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ONTARIO GEOLOGICAL SURVEY

Open File Report 6010

Regional Distribution of Platinum, Palladium, Gold, Kimberlite Indicator Minerals and Base Metals in Surficial Sediments, River Valley Area, Northeastern, Ontario

by

N.P. Tardif

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Abstract

The River Valley area was chosen for a study of platinum and palladium response in overburden materials. It is has recently been a target of increased mineral exploration due to numerous platinum group element (PGE) occurrences having been identified. A drift sampling program was initiated during which 171 C-horizon subglacial till, 99 B-horizon soils and 166 humus samples were collected. Samples were collected on a regional scale (1 sample per 3 km^2) and within 2 detailed case study areas (Dana Lake and Azen Creek zones) located in the vicinity of previously identified zones of mineralization (Pd-Pt-Au and Cu-Ni).

The examination of platinum group elements (Pt and Pd), Au, Cu and Ni in surficial materials identified the level and contrast of element responses within different surficial sediment types. Within each sampling media, the character of dispersal patterns was observed and comparisons were made. Although, most sampling media showed relatively anomalous values within the case study areas where known bedrock mineralization occurs, the non-ferromagnetic fraction of heavy minerals demonstrated the highest geochemical values.

Thirty-two samples were selected for metamorphosed massive sulphide indicator mineral (MMSIM) and kimberlite indicator mineral (KIM) analysis. From these samples, 3"G10" Cr-pyrope garnets were recovered as well as variety of other indicator minerals (chromites, Mg-ilmenites, Cr-diopsides, gahnites and red rutile). Also, gold grains and platinum group minerals (sperrylite and stibiopalladinite) were recovered from the heavy mineral concentrate of the selected 32 samples.

The data presented in this report is part of a larger dataset that is being released in conjunction with this Open File Report. The dataset consists of sample location information, heavy mineral weight data, gold grain size and shape data, ICP and INAA geochemical data. Data is contained within Tardif (2000), Miscellaneous Release Data 53 (Till, B-horizon Soils and Humus Compositional Database, River Valley area, Northeastern Ontario).

Introduction

Mineralogical and geochemical analyses of surficial sediment samples have proven to be effective tools in exploration for kimberlites, volcanogenic massive sulphide (VMS), platinum group element (PGE) and gold deposits (Fuchs and Rose 1974; Dilabilo 1988; Gunn 1989; Mountain and Wood 1988; Fletcher 1988; Wood and Vlassopoulos 1990; Coker et al. 1991; Cook et al. 1992; Bajc 1993; Cheng et al. 1997). A variety of sampling surveys utilizing materials including till, B-horizon soils, humus, stream sediments and glaciofluvial deposits have defined those media and laboratory methods most effective for drift geochemistry programs (Dilabilo 1988; Fletcher 1988; Wood and Vlassopoulos 1990; Coker et al. 1991; McClenagnan 1992; Hall and Bonham-Carter 1988; Riese and Arp 1986). Once indicator minerals and metals are detected, the observations can be applied to the geochemical and heavy mineral data derived from regional surveys to highlight potential areas for exploration.

The River Valley mafic intrusion, situated east of Sudbury, Ontario (Figure 1), is of great interest for mineral exploration because of the numerous platinum group element (PGE) occurrences that have been identified (Easton and Hrominchuk 1999; Hrominchuk 1999; Barr 1999). As a result, exploration for PGEs, Cu, Ni and Au by a number of mineral exploration firms is now underway. In addition to the present study, the Ontario Geological Survey (OGS) is also completing regional and detailed mapping of the intrusion (Easton and Hrominchuk 1999; Hrominchuk 1999). The surficial material sampling program that is the focus of this report covers 2000 km^2 of the area within and surrounding the River Valley intrusion (Figure 2).

The study area is located approximately 35 to 70 km east of Sudbury, in northeastern Ontario (Figure 1). An extensive and thick cover of glacial sediments was deposited across this area by a southward flowing ice advance and subsequent glaciolacustrine deposition. A regional sampling study and 2 detailed case studies were completed, where C-horizon tills, B-horizon soils and humus samples were collected from a total of 172 sample sites (Figure 2). The detailed case studies were completed in the vicinity of previously identified zones of mineralization near the contact between the River Valley mafic intrusion and surrounding rocks, within Dana Township (Figure 2).

Previous and recent mineral exploration in the River Valley intrusion indicated significant mineralization potential within the area, with grades of up to 12.6 g/t Pt + Pd + Rh occurring in the Dana Lake zone (Barr 1999). Background values for Pt+Pd+Rh+Au throughout the intrusion are approximately 30 ppb (Easton and Hrominchuk 1999).

The objective of the present study was to complete a program of drift geochemistry to further evaluate the mineral potential of the area. Specifically, sampling and analysis was designed to identify: 1) background values for precious and base metals within surficial materials of the River Valley area and whether anomalous values are present; 2) whether PGEs, gold and base metals are present within different sampling media (i.e., C-horizon till, B-horizon soil and humus); 3) whether PGEs, gold and base metals (Cu, Ni) are present and at what levels within the ferromagnetic fraction of the heavy mineral concentrates; 4) the presence of metamorphic massive sulphide indicator minerals; and 5) the presence of kimberlite indicator minerals.

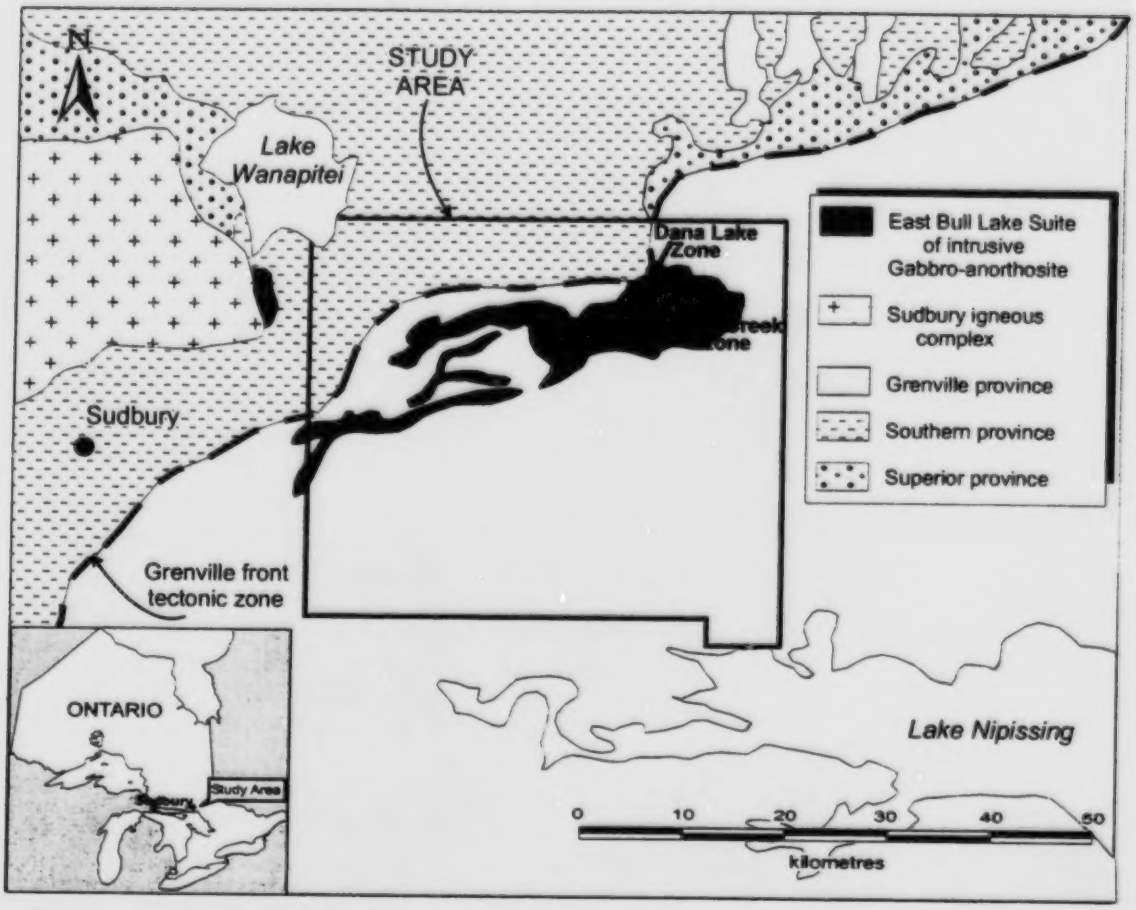


Figure 1: Location and geology map of study area.

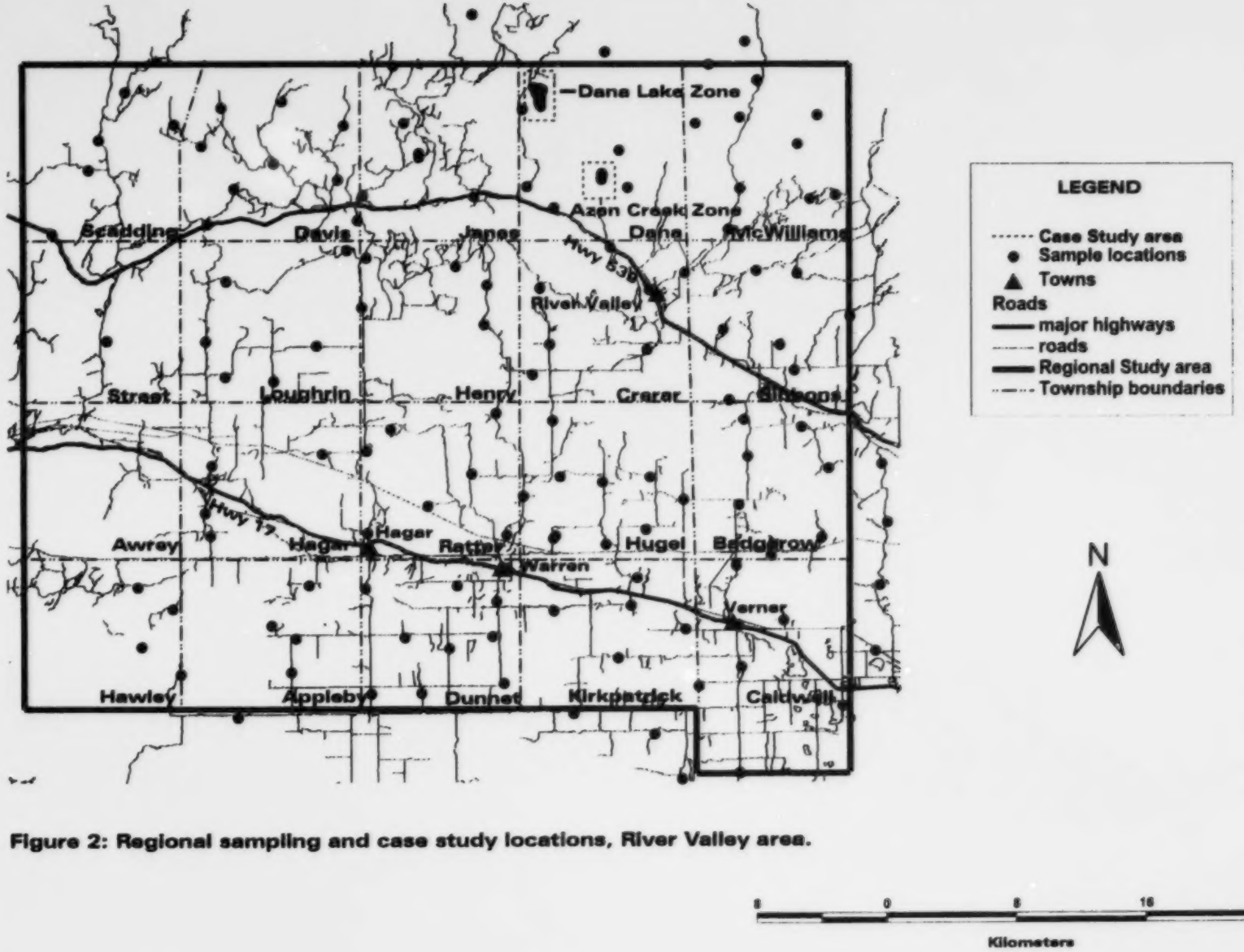


Figure 2: Regional sampling and case study locations, River Valley area.

STUDY AREA

A total of 131 sites were sampled within the 20 townships that make up the study area. The townships are: Scadding; Street; Awrey; Hawley; Davis; Loughrin; Hagar; Appelby; Janes; Henry; Ratter; Dunnet; Dana; Crerar; Hugel; Kirkpatrick; McWilliams; Gibbons; Badgrow; and Caldwell (Figure 2). Samples were collected in areas accessible by road and trails at a density of approximately 1 sample per 3 km^2 (Tardif 1999). Two case study areas, the Dana Lake zone and the Azen Creek zone, contain a total of 44 sample sites. Case study areas are located within Dana township, in the north central part of the study area.

The study area is represented on 4, 1:50 000 scale maps of the National Topographic Series, namely the Capreol (41-I/10), Coniston (41-I/7), Glen Afton (41-I/9) and Verner (41-I/8) sheets. The sampling area is bounded by longitudes 80°42′ W and 80°02′ W and latitudes 46°43′ N and 46°16′ N.

Regional Geology

BEDROCK GEOLOGY

Six main rock types are present within the study area. These include: 1) the East Bull Lake suite of mafic and ultramafic intrusive rocks; 2) felsic intrusive rocks; 3) Nipissing diabase sills; 4) gneisses of metasedimentary origin; 5) undifferentiated mafic rocks; and 6) felsic migmatites and gneisses (Figure 3).

The 2475+2/-1 Ma (Easton and Hrominchuk 1999) River Valley intrusion is composed of mafic and ultramafic rocks that are part of the Early Proterozoic East Bull Lake suite of intrusions. It is located within the north central part of the study area and occurs in proximity to the Grenville Front Tectonic Zone within the Grenville Province (Figure 3). A 1:50 000 scale map by Lumbers (1975) indicats that the River Valley intrusion was composed of anorthosite and anorthositic gabbro. However, more recent mapping by Easton and Hrominchuk (1999) and Hrominchuk (1999) shows that less than 10% of the intrusion is made up of anorthosite. According to Easton and Hrominchuk (1999), the main rock types found within the intrusion are gabbro, norite, gabbronorite, leucogabbronorite and leuconorite. Metamorphism of these rocks ranges from low grade with primary igneous textures present to upper amphibolite facies or higher (Hrominchuk 1999).

According to Hrominchuk (1999) mineralization occurs mainly in 2 areas within the intrusion: 1) in an inclusion/fragment-bearing zone where inclusions range from pyroxenite to leucogabbronorite in composition; and 2) along the contact of the intrusion.

QUATERNARY GEOLOGY

Approximately 20 000 years ago, the study area was covered by the Laurentide ice sheet. Deglaciation of the Sudbury area, approximately 9500 to 11 000 years ago, resulted in the formation of large glacial lakes at the receding glacier margin. The last glacial lakes that occupied the study area drained approximately 5500 years ago. The record of these glacial lakes is found in the glaciolacustrine (silt- to clay-rich) sediments that form the low relief lake plain in the southern part of the study area. Ice-contact stratified sediments are found in glacial

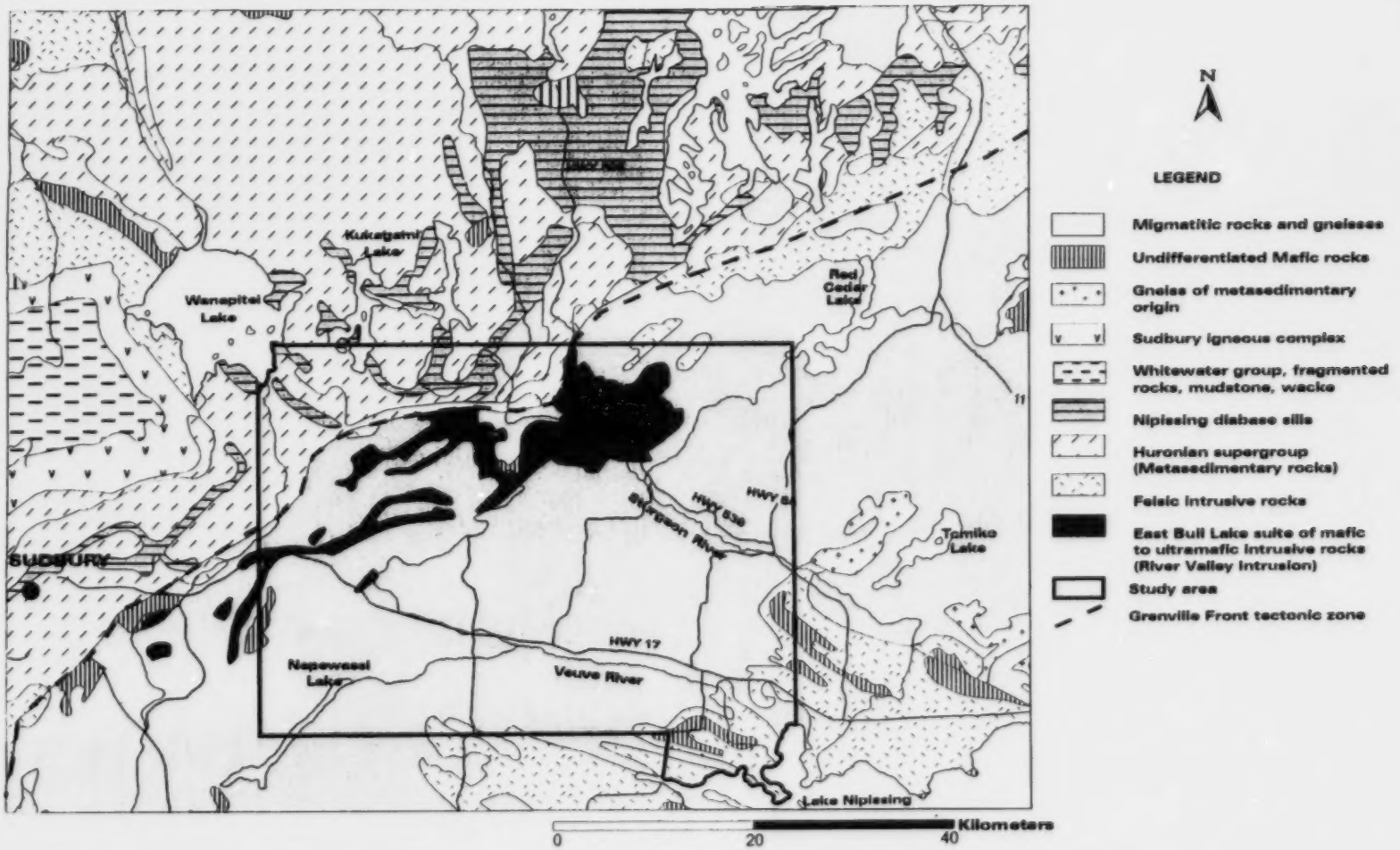


Figure 3. Bedrock geology of study area (Modified from Ontario Geological Survey 1991)

landforms such as eskers and subaqueous fans in addition to outwash sediments. Ice-contact deposits are present along bedrock controlled valleys in the northern part of the study area (Tardif 1999).

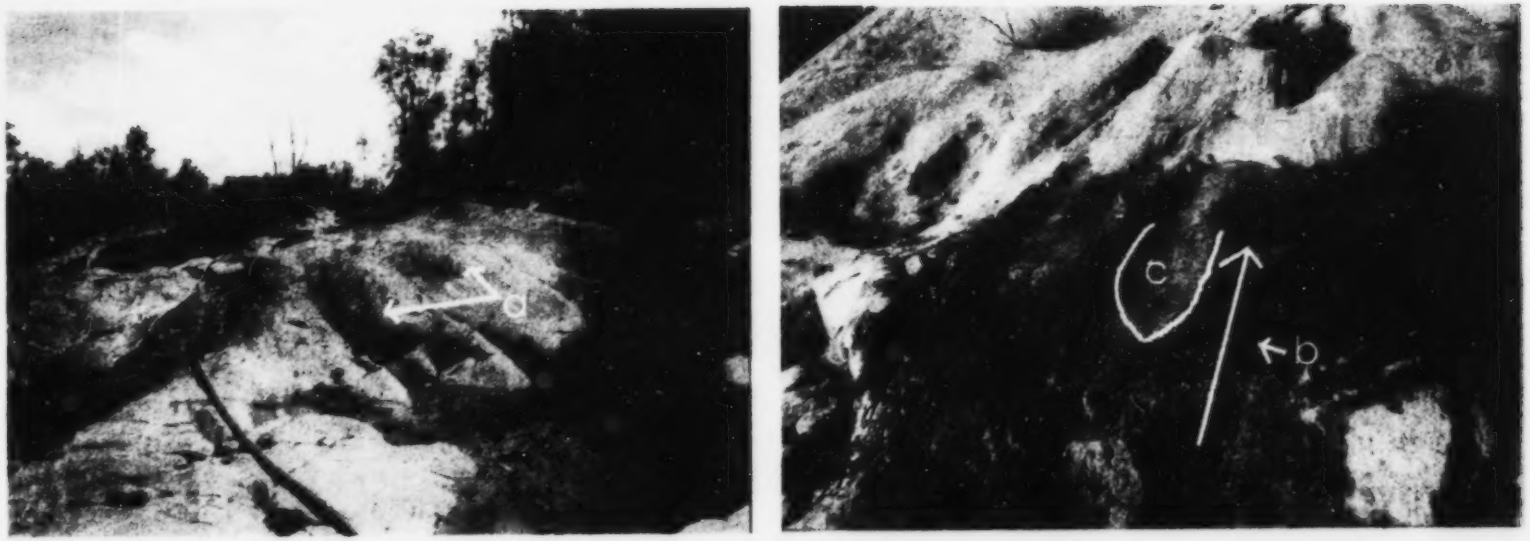
In the study area only one till was identified. The till is light grey to olive grey in colour and contains a silty-sand to sandy-silt matrix. In the northern part of the study area, sandy till occurs as veneer overlying bedrock. Within the bedrock controlled valleys, thick deposits of outwash sands and gravels predominate. This outwash material continues into the central part of the study area where a series of deltaic deposits are present. In the southern part of the study area, the till matrix is siltier and can be sampled along the margins of bedrock outcrops which protrude above the lake plain (Tardif 1999).

Glacial grooves, striations and chatter marks found on bedrock surfaces (Figure 4) provide good indicators for the direction of ice flow within the study area. Ice flow ranged between 165° and 195°, with a mean orientation directed toward the south. A possible second ice flow direction was also observed, with a general flow direction toward the south-southwest (210°). This second ice flow direction appears to be older than the first and was observed at several sites in the northern part of the study area (Figure 5).

Sampling

Different soil horizons often show different responses with respect to their PGE and/or gold content (Gleeson and Sheehan 1987; Cook and Fletcher 1993; Coker et al. 1991). Thus, it is advantageous to sample each horizon in order to determine which ones provide the best response. In the River Valley area, a typical soil profile (bottom to top) comprises a C-horizon till, and B and A soil horizons (Figure 6). The C-horizon till is the material lowest in sequence and can vary from being absent to tens of meters in thickness. Throughout the River Valley area, it is very poorly sorted and contains on average 30% striated and faceted clasts of subglacial origin. C-horizon till is grey in colour and has not been readily affected by the effects of weathering. The B-horizon soil is the zone of accumulation and lies above the C-horizon. It is an oxidized, brownish-red layer that varies in thickness between 2 and 50 cm. The till derived B-horizon is usually more silty than the unoxidized C-horizon till and generally contains less clasts. The A-horizon is the thinnest horizon, ranging from 2 to 6 cm. It is a light grey leached horizon, usually void of mobile minerals which have moved into the B-horizon. Because of its thickness and the leaching effect, A-horizon samples were not collected in this study. Above the A-horizon is a generally well-developed, black organic-rich humus layer ranging between 2 to 10 cm in thickness.

A total of 172 sample sites were selected in the study area (Figure 7) (Appendix A-1, this report). From these sample sites, 166 humus, 99 B-horizon, and 171 C-horizon till samples were collected. Where possible, unoxidized till was collected from hand dug test pits and road cuts. On average a 12 kg bag of sieved till (7 mm sieve size) was collected and submitted for heavy mineral concentrate analysis. A total of 32 samples were submitted for kimberlite indicator mineral and metamorphosed massive sulfide indicator mineral (MMSIM) processing. From each sample site a 2 to 3 kg bag of sieved till (7 mm sieve) was also collected and submitted for geochemical analysis (- 63 μm) along with a 2 to 3 kg bag of B-horizon soil (- 63 μm) and a sieved humus sample (7 mm sieve) (- 177 μm).



(A) (B)

Figure 4: Exposed, glaciated surfaces in the Dana Lake area showing: (A) whaleback forms (a) and (B) small scale features such as strations (b), spindle flute forms (c) and glacial grooves. Striations vary between 180° and 220°. Ice flow in both photos is away from the reader.

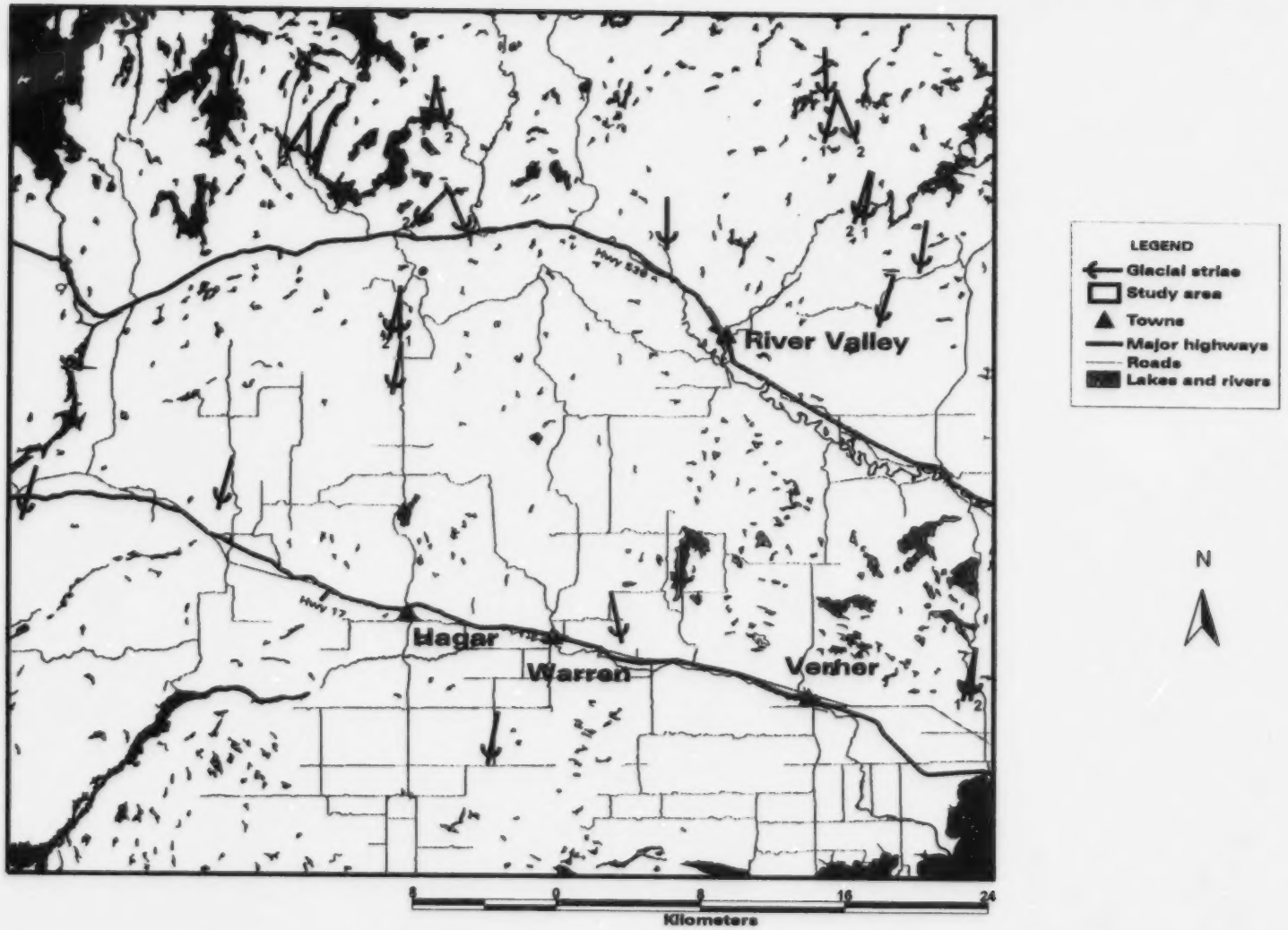


Figure 5: Regional distribution of glacial striae. Numbers indicate sequence of formation, i.e., 1 is the oldest.

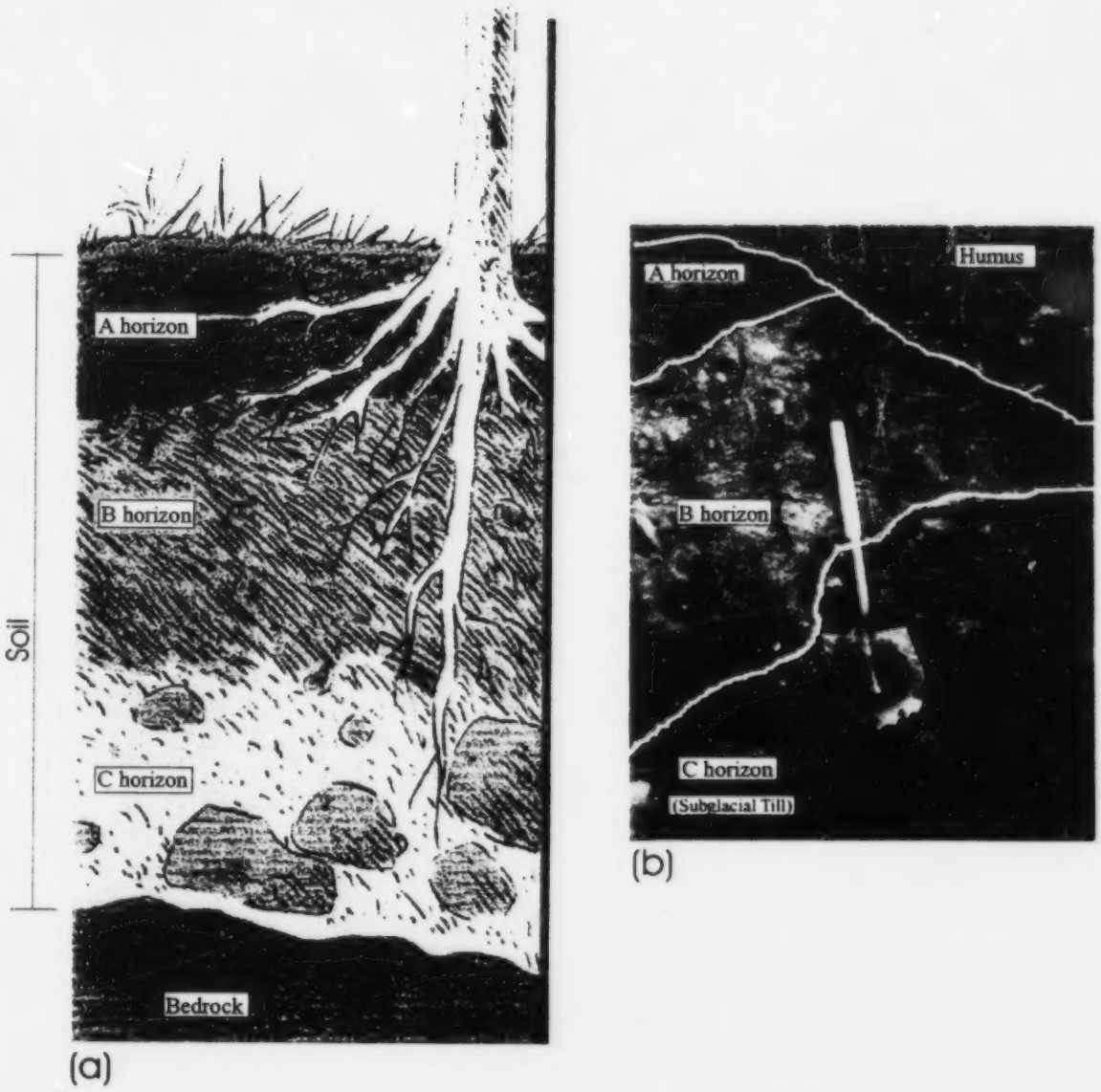


Figure 6: Generic soil profile (a) and typical soil development in the River Valley area (b). (Modified from Brady 1984)

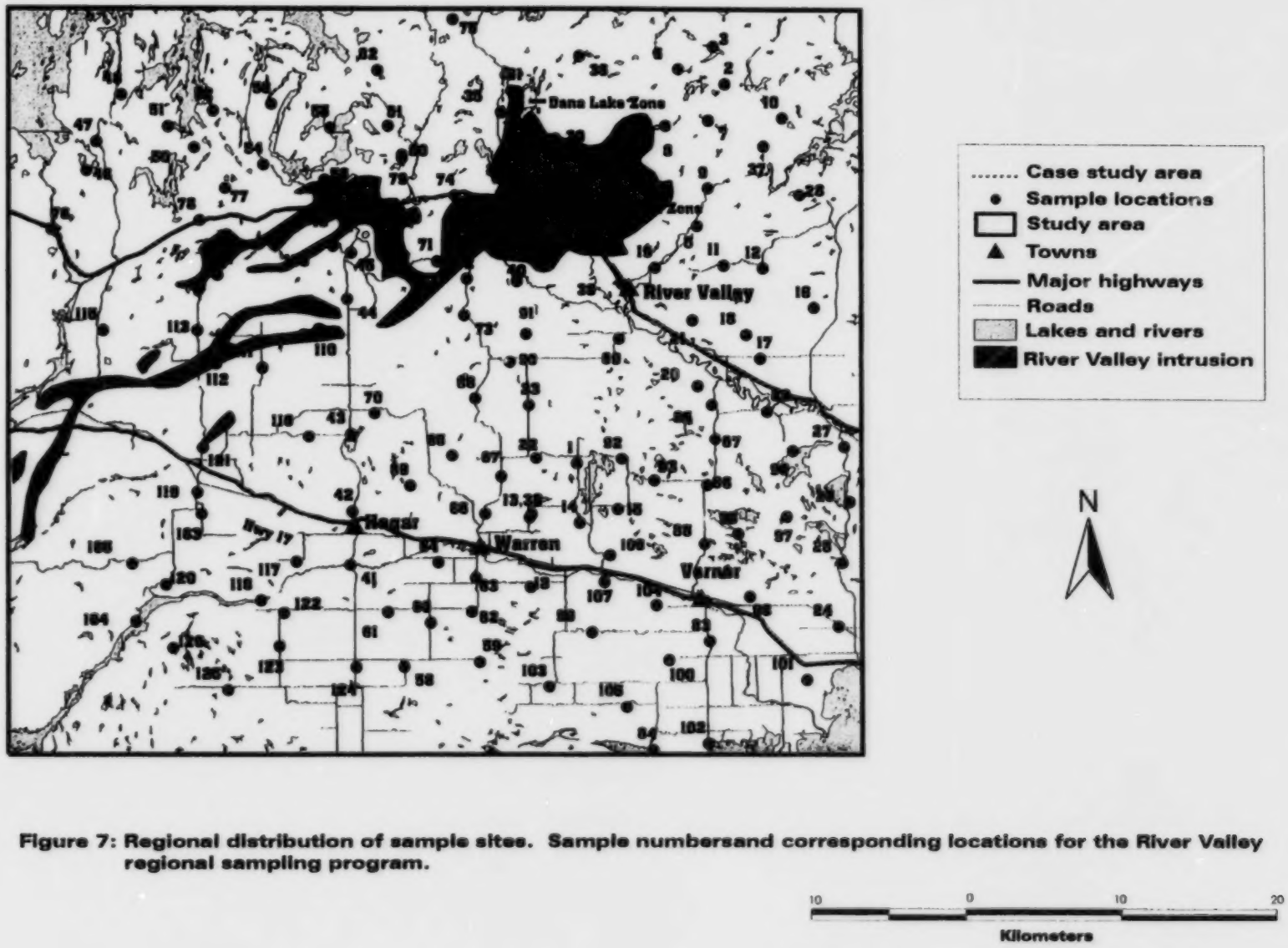


Figure 7: Regional distribution of sample sites. Sample numbersand corresponding locations for the River Valley regional sampling program.

Pebble Lithology

Till samples collected near bedrock surfaces often contain pebble lithologies that reflect the underlying bedrock and are likely to have a proximal source. Till samples collected some distance from the bedrock surface may contain exotic clasts which indicate significant transportation of the till. Other characteristics of pebbles such as size, shape and percentage of pebbles present in the sample can also be used to determine proximity to source. A sample containing a high percentage of large, angular pebbles most likely reflects derivation from a proximal source. Whereas, a sample containing a low percentage of small, rounded pebbles is more likely to reflect transport some distance from its source area.

An average of 100 pebbles were collected at each sample location; these were identified to determine till provenance. In general, clasts were composed of metasediments, intrusives, metamorphic/mafic intrusives, volcanics, metamorphic/mafic volcanics, schists and gneisses. Reccuring rock types within these categories include; Huronian sediments, granite, gabbro, diabase, greenstone, pyroxenite, peridotite and gneisses. Pebbles were often striated and faceted indicating subglacial deposition. Some striated clasts and boulders could be observed *in-situ* within till sections. These clasts and boulders clearly indicated ice flow toward the south-southwest. Pebble lithologies for each sample are recorded in Tardif (2000, Appendix E).

Metasedimentary, gneissic and mafic metaintrusive lithologies are the dominant rock types covering the study area (Figure 3). As a consequence, metasedimentary and gneissic pebbles are very abundant in almost all samples (Tardif 2000, Appendix E) and indicate relatively proximal sources (less than 20 km). Samples containing mafic metaintrusive pebbles indicate that part of the sample has been derived from mafic bedrock, possibly the River Valley mafic intrusion.

Figure 8 illustrates an example of pebble lithologies (sample 99-NPT-152) that have been derived from a proximal source. This sample was collected on the northern fringe of the River Valley mafic intrusion. Mafic intrusive pebbles comprise 15% of the total pebbles present in this sample. Metasedimentary rocks are very abundant (58%) and correspond with a body of metasedimentary rocks located less than half a kilometer north of the mafic intrusion. Other pebble lithologies reflect rock types that were derived by the glacier less than 10 km north of the sample location.

Case Study Areas

DANA LAKE ZONE

The Dana Lake zone is located near the eastern margin of the River Valley intrusion. Mineralization within this area is widespread and grab samples of up to 12.6 g/t Pt+Pd+Rh (Barr 1999) have been reported from one of the exposed mineralized areas.

A sampling grid aligned generally parallel to ice flow direction was established in this zone. Thirty-four soil samples were collected in this area at 50 m intervals (Figure 9). Unoxidized till, B-horizon soil and humus samples were taken 200 m up ice from the Road and North zones and up to 900 m down ice of these zones. In general, samples were collected from hand dug test pits and trenches up to 4 m in depth.

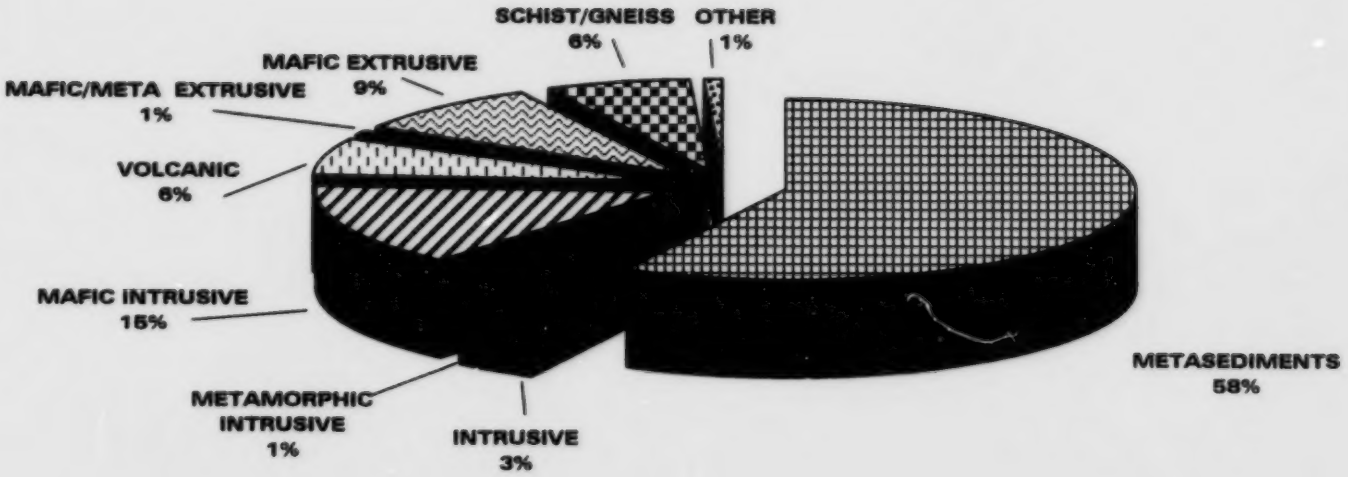


Figure 8: Pebble lithologies for sample 99-NPT-152.

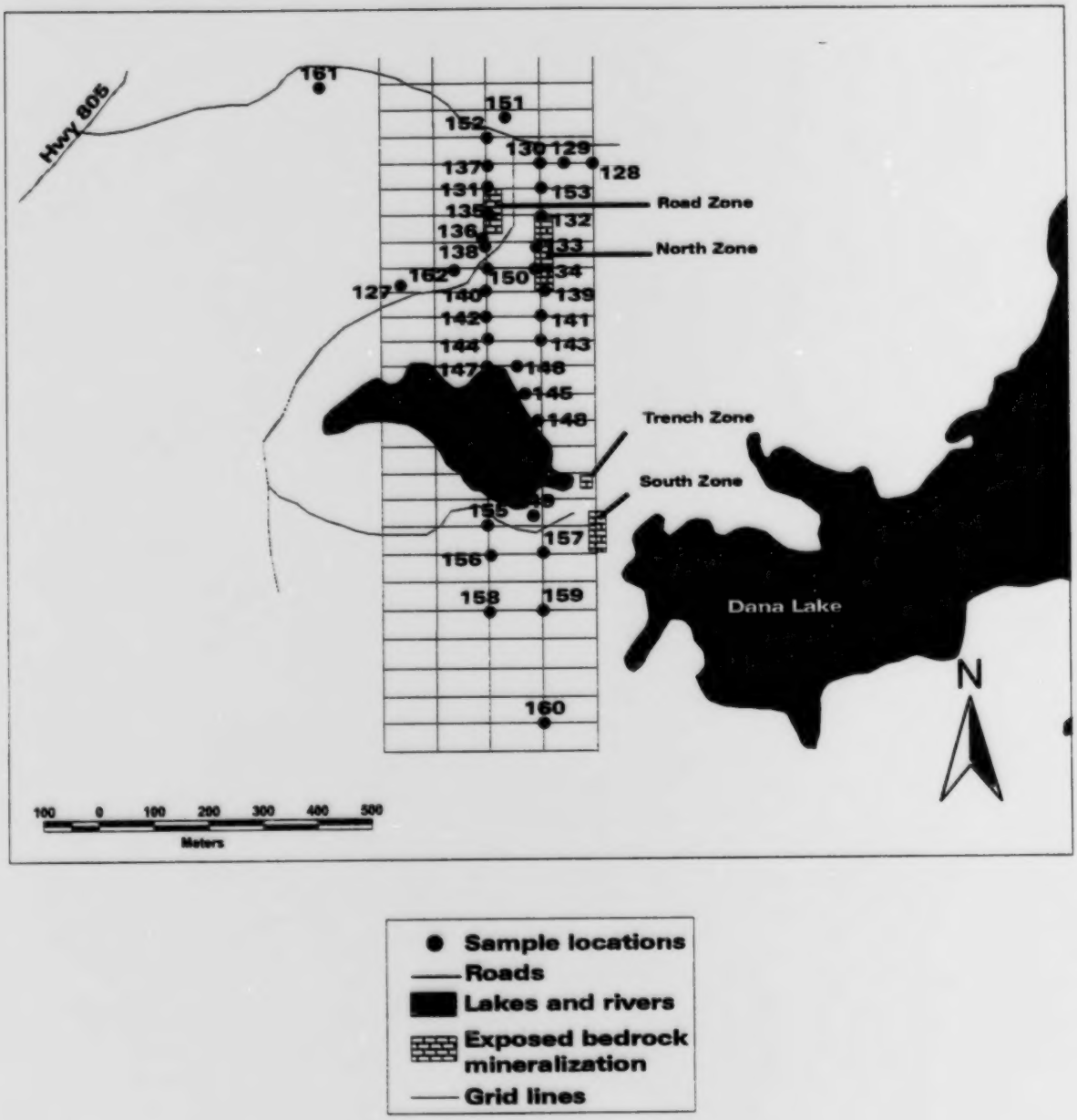


Figure 9: Sample locations within the Dana Lake case study area.

AZEN CREEK ZONE

Approximately 6 km south-east of the Dana Lake zone (Figure 10) a second mineralized zone has been exposed. This area is further from the contact of the River Valley intrusion with its surrounding rocks than the Dana Lake zone, however, significant mineralization, up to 3 g/t Pt+Pd+Rh (Barr 1999) has been reported.

Within this area, 9 C-horizon till, B-horizon soil and humus samples were collected at 50 m intervals along one traverse trending 190°, that is parallel to ice flow direction (Figure 10). A backhoe was used to obtain samples from up to 8 m depth in some areas. Samples were taken up to 100 m up ice of the mineralized zone and up to 250 m down ice, until till could no longer be sampled due to the depth of other overlying overburden (sand and gravel).

Sample Collection, Processing and Analysis

LABORATORY METHODS

Humus

Humus samples were air dried at less than 80°C and sieved to 0.080 mm until approximately 15 to 30 g of material was collected.

Samples were separated into 2 fractions. Approximately 1 gm was submitted for inductively coupled plasma-mass spectrometry (ICP-MS) to the Geoscience Laboratories, in Sudbury. Approximately 25 gm was submitted for instrumental neutron activation analysis (INAA) and Pb fire assay ICP-MS (Figure 11).

B- and C-horizon soils

Ninety-nine B-horizon and 170 C-horizon till samples were air dried at less than 80°C and sieved to - 63 μm.

Prepared samples were split into 3 sub-samples that were submitted to the Geoscience Laboratories for: 1) inductively coupled plasma-mass spectrometry (ICP-MS) with aqua-regia digestion (1 gm); 2) inductively coupled plasma optical emission spectrometry (ICP-OES) with aqua-regia digestion (1 gm); and 3) Pb fire-assay ICP-MS, analyzing for Au, Pt and Pd (10gm). A fraction of the sample (30 gm) was also sent for instrumental neutron activation analysis (INAA) (Figure 12).

SAMPLE PREPARATION

Before undergoing analysis, each sample was prepared by either an aqua regia digestion, closed beaker digestion or a lead fire assay preparation.

Aqua regia digestion is intended primarily for soils and sediments. The final solutions are analysed by ICP-MS and ICP-OES. In a centrifuge tube, to 0.5 gm of sample is added 3 ml of nitric acid (HNO_3) and 4 ml of hydrochloric acid (HCl). After mixing, digestion occurs at room temperature as the sample is left sitting for a period of 16 to 24 hours. Centrifuge tubes

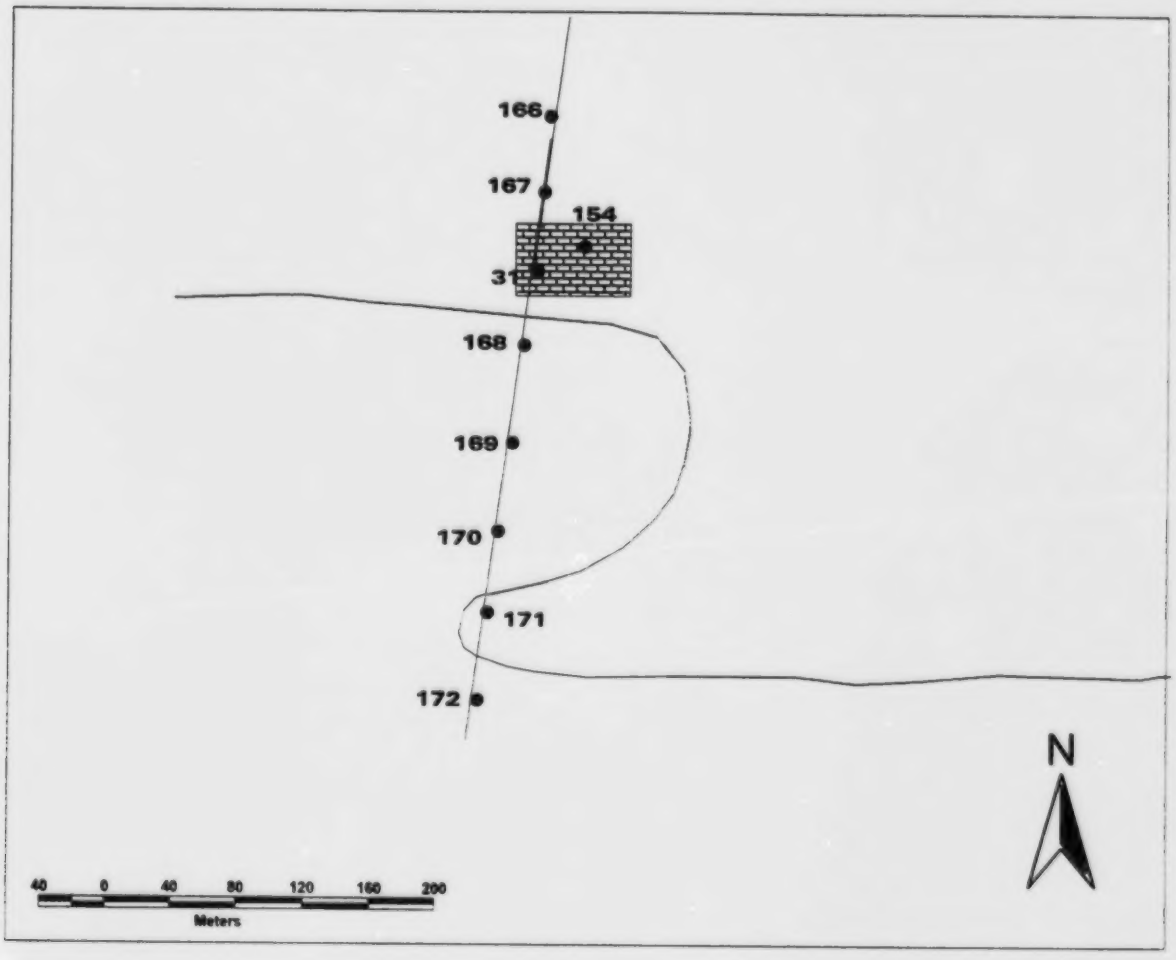


Figure 10: Sample locations within the Azen Creek case study area. Refer to Figure 7 for regional location.

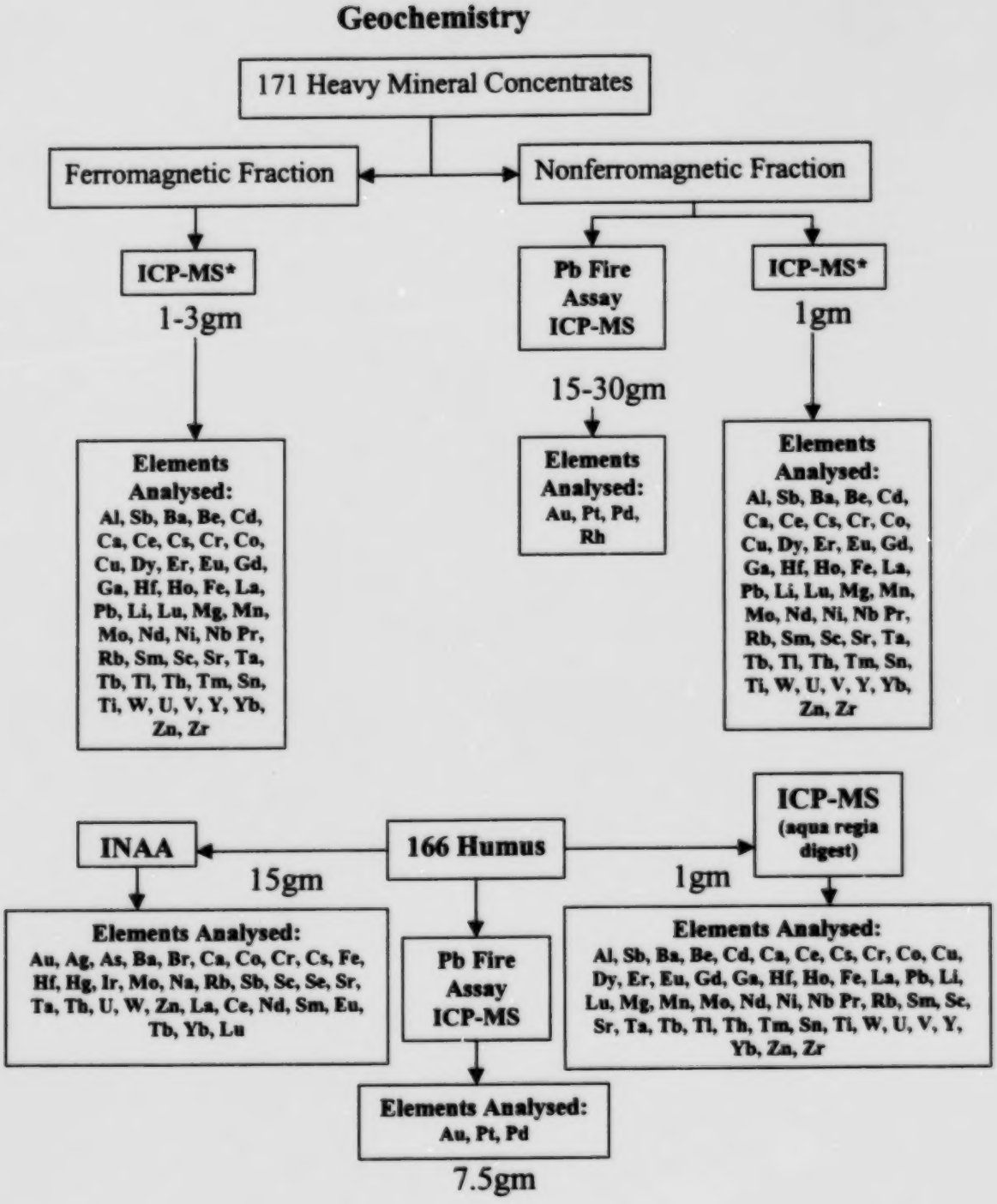

Geochemistry
171 Heavy Mineral Concentrates
Ferromagnetic Fraction
Nonferromagnetic Fraction
ICP-MS*
1-3gm
Pb Fire Assay ICP-MS
15-30gm
ICP-MS*
1gm
Elements Analysed: Al, Sb, Ba, Be, Cd, Ca, Ce, Cs, Cr, Co, Cu, Dy, Er, Eu, Gd, Ga, Hf, Ho, Fe, La, Pb, Li, Lu, Mg, Mn, Mo, Nd, Ni, Nb Pr, Rb, Sm, Sc, Sr, Ta, Tb, Tl, Th, Tm, Sn, Ti, W, U, V, Y, Yb, Zn, Zr
Elements Analysed: Au, Pt, Pd, Rh
Elements Analysed: Al, Sb, Ba, Be, Cd, Ca, Ce, Cs, Cr, Co, Cu, Dy, Er, Eu, Gd, Ga, Hf, Ho, Fe, La, Pb, Li, Lu, Mg, Mn, Mo, Nd, Ni, Nb Pr, Rb, Sm, Sc, Sr, Ta, Tb, Tl, Th, Tm, Sn, Ti, W, U, V, Y, Yb, Zn, Zr
ICP-MS (aqua regia digest)
INAA
166 Humus
15gm
1gm
Elements Analysed: Au, Ag, As, Ba, Br, Ca, Co, Cr, Cs, Fe, Hf, Hg, Ir, Mo, Na, Rb, Sb, Sc, Se, Sr, Ta, Th, U, W, Zn, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu
Pb Fire Assay ICP-MS
Elements Analysed: Al, Sb, Ba, Be, Cd, Ca, Ce, Cs, Cr, Co, Cu, Dy, Er, Eu, Gd, Ga, Hf, Ho, Fe, La, Pb, Li, Lu, Mg, Mn, Mo, Nd, Ni, Nb Pr, Rb, Sm, Sc, Sr, Ta, Tb, Tl, Th, Tm, Sn, Ti, W, U, V, Y, Yb, Zn, Zr
Elements Analysed: Au, Pt, Pd
7.5gm

Figure 11: Geochemical flow charts for heavy mineral concentrates and humus samples. ***(*Closed beaker digestion)***

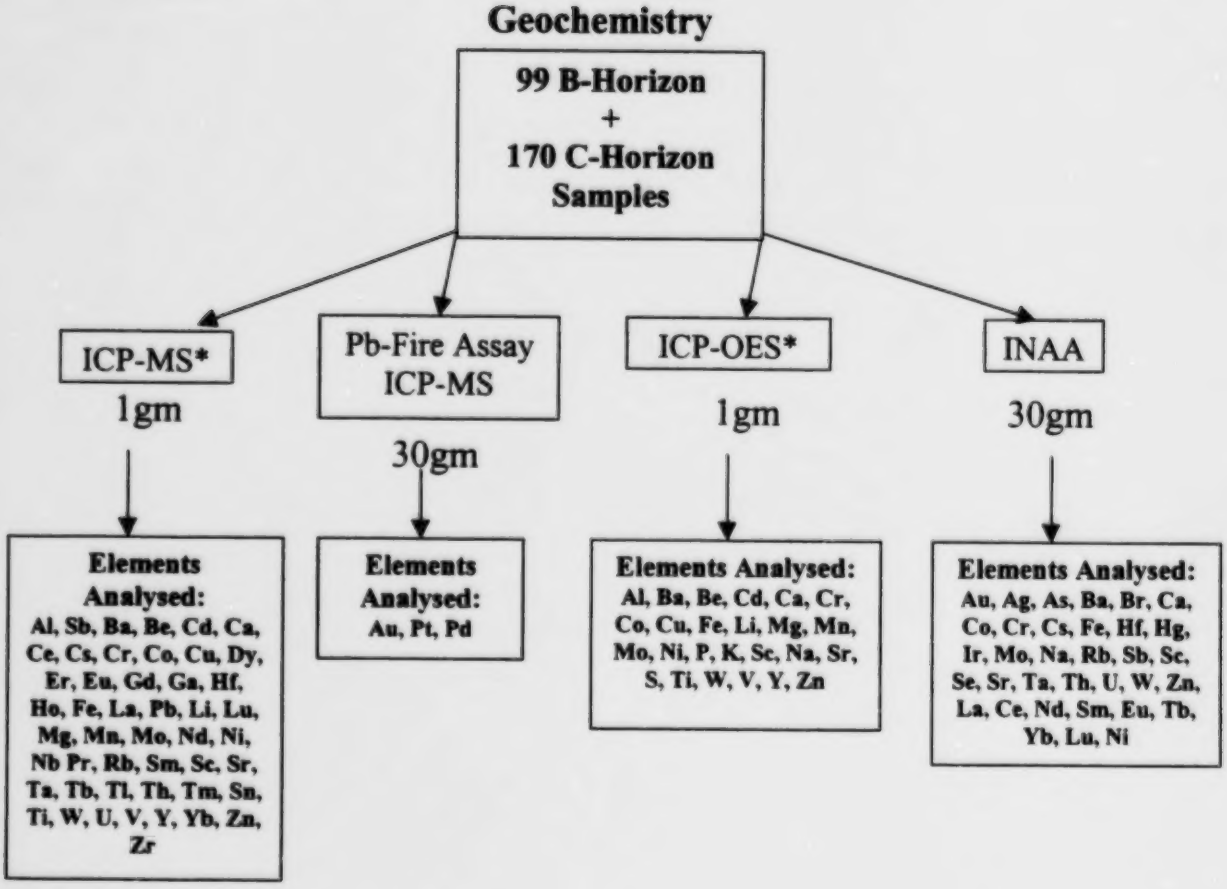

Geochemistry
99 B-Horizon
+
170 C-Horizon
Samples
ICP-MS*
1gm
Elements Analysed:
Al, Sb, Ba, Be, Cd, Ca, Ce, Cs, Cr, Co, Cu, Dy, Er, Eu, Gd, Ga, Hf, Ho, Fe, La, Pb, Li, Lu, Mg, Mn, Mo, Nd, Ni, Nb Pr, Rb, Sm, Sc, Sr, Ta, Tb, Tl, Th, Tm, Sn, Ti, W, U, V, Y, Yb, Zn, Zr
Pb-Fire Assay
ICP-MS
30gm
Elements Analysed:
Au, Pt, Pd
ICP-OES*
1gm
Elements Analysed:
Al, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Li, Mg, Mn, Mo, Ni, P, K, Sc, Na, Sr, S, Ti, W, V, Y, Zn
INAA
30gm
Elements Analysed:
Au, Ag, As, Ba, Br, Ca, Co, Cr, Cs, Fe, Hf, Hg, Ir, Mo, Na, Rb, Sb, Sc, Se, Sr, Ta, Th, U, W, Zn, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, Ni

Figure 12: Geochemical flow chart for B-horizon soil and C-horizon till ***(*Aqua Regia digestion).***

containing the sample are then heated to 100°C for 1 hour, removed and allowed to cool. Fifty milliliters of 5 ppm ReRu is added and the sample is brought to volume (50 ml) by adding distilled deionized water. The sample is left overnight and is then transferred to a test tube where it is ready for analysis by ICP-MS and ICP-OES (Bowins 1999a).

Closed beaker acid digestion allows a continuous exposure of the sample to the acid. This technique prevents the loss of certain mineral phases (Hf, Ta, Nb, Zr) that are resistant to acid dissolution. Final solutions are analysed by ICP-MS. In this method, 0.2 gm of sample is mixed with a solution containing hydrofluoric acid (HF), hydrochloric acid (HCl) and perchloric acid ($HClO_4$). The resulting solution is tightly capped then placed into an oven and heated at 120°C for a period of approximately 7 days. After cooling, a second solution containing deionized distilled water (DDW), hydrochloric acid and perchloric acid is added and the total volume of liquid is placed on a hot plate and allowed to evaporate to dryness. Small amounts of concentrated HCl, concentrated nitric acid (HNO_3), concentrated HF and DDW are added respectively, and subsequently heated to reduce volume to 10 ml. An internal standard is added to the solution, which is then brought to volume with HNO_3. The solution is then transferred to a 12 ml test tube and is ready for analysis by ICP-MS.

A lead fire-assay preparation requires a large amount of sample (30 gm), but is considered the most reliable means of preparation for analysis of most geological materials (Hall and Bonham-Carter 1988). This type of preparation for ICP-MS or ICP-OES analysis is accomplished by using 3 processes: 1) a lead-fire assay silver bead or "prill" collection; 2) dissolution of the Pb-Fire assay silver prill; and 3) ICP determination of Au, Pd and Pt. Each dried and sieved sample is subject to a cupellation process that results in the formation of a Ag prill. This prill is placed in a test-tube along with 0.5 ml of 3M HNO_3 and is dissolved by heating at 90°C for 30 min. A half (0.5) ml of 2.5M HCl is then added to precipitate Ag as AgCl. Analyte determination by relative ICP intensity measurements is done along with calculation of Au, Pt, and Pd concentrations in the sample (Bowins 1999b, 1999c, 1999d).

GEOCHEMISTRY

After sample preparation, samples are ready for geochemical analysis. Each method has certain advantages and disadvantages for sample analysis. Some are better at detecting certain elements and others have better detection limits.

Inductively coupled plasma mass spectrometry (ICP-MS) provides reasonable detection limits (ppb) in analysis of trace elements in dilute solution. Samples prepared by acid digestion or lead fire assay are brought into solution, mixed by acid attack and an elemental determination is undertaken on the Perkin-Elmer Elan 5000™ inductively coupled plasma mass spectrometer (Bowins 1999e).

Inductively coupled plasma-optical emission spectrometry (ICP-OES) is used to detect inorganic elements in acidic solutions. Samples are dissolved in acid and an instrumental response of each element is calculated. This is followed by a measurement of analyte signal responses where elemental calculations are made for each sample (Bowins 1999f).

Instrumental neutron activation analysis (INAA) provides good detection limits for elements such as Cr, Co and rare earth elements. In this method, 15 gm of humus sample and 30 gm of B and C horizon soil sample is pressed at 40,000 pounds to produce a briquette (40 mm diameter, 10 mm thick). Briquettes are weighed and irradiated. Samples are allowed to decay for

7 days and then counted for 400 seconds on the high purity Ge detector-MCA-computer system where results are evaluated (Activation Laboratories Ltd. 1999).

Quality Control

Quality control was invoked for all sample analysis. Approximately every 20th sample within the analytical sequence was a duplicate sample so as to test for precision of laboratory methods. Certified reference materials were also inserted at approximately every 20th sample. Geochemical results are known for certified reference materials and they are inserted to test for accuracy of laboratory methods and for drift of the analytical instrument between batches.

Quality control data tables were created for each element analyzed as pat of this project (Tardif 2000, Appendix J). These tables display: 1) the method detection limit for each element; 2) duplicate data, such as the number of duplicates used and calculated precision derived from X, Y precision control charts; and 3) types of standards, including the reference assay results, the number of standards used, the mean laboratory assay results, and the standard deviation. The standard deviation indicates the typical or standard amount that a value is likely to differ from the mean of a set of values (Chapman and Monroe 1993).

Geochemical results were evaluated taking the method detection limit and precision of each element into account. Laboratory methods showing the lowest detection limits and giving the best precision numbers were selected to represent the best results for a given element.

Platinum and Palladium

INTRODUCTION

In the case of platinum and palladium, ICP-MS with a lead fire-assay preparation was found to be the most precise and reliable analytical method for the determination of PGE geochemistry (Appendix K1 and K2, this report). Detection limits were 0.3 ppb for Pt and 0.7 ppb for Pd in B-horizon and C-horizon samples and 0.4 ppb for Pt and Pd in humus samples. Precision of data was generally good especially at higher concentrations (Appendix J1, this report). The poor reproducibility of results for PGEs in samples having lower concentration may be largely due to the inhomogeneous distribution of Pt and Pd within the samples, i.e., the nugget effect (Clifton et al. 1969; Harris 1982; Cook et al. 1992).

In theory, a subglacial till sample collected close to bedrock provides the best representation of bedrock geochemistry and increases the chance that sample components were derived by the glacier from a near-by up-ice source area. This is true in most cases where the topography is flat, however, in areas with variable topography, material picked up by the glacier, such as mineralized rock, may be deposited anywhere within the till stratigraphy. For this reason, samples from different depths should be collected. As well, through time, soils and bedrock are exposed to a variety of outside influences such as hydromorphic dispersion and weathering, which affects the behavior of minerals and other constituents in surficial environments.

In the case of PGEs, lack of information on their behavior in surficial materials accounts, in part, for the limited application of drift geochemistry to PGE exploration using surficial sediments. A study done within the Stillwater complex by Fuchs and Rose (1974) indicated 4 factors that influence the behavior of Pt and Pd during weathering: 1) pH; 2) Eh; 3) complex concentration of soil water (e.g., chloride); and 4) mode of occurrence in the primary rock before weathering. The study by Fuchs and Rose (1974), along with several previous studies (Wagner

1929; Ottemann and Augustithis 1967; Wood and Vlassopoulos 1990) indicated platinum and palladium mobility in geochemical fluids within surficial environments. Wood and Vlassopoulos (1990) showed that high concentrations of Pd are present in solution within lakes and groundwaters in the Lac Sheen area of Quebec where they form soluble complexes such as chlorides and hydroxides, depending on the pH, fO_2, temperature and ligand concentration of the fluid. Within these complexes, palladium was found to be more consistent in its distribution than platinum because palladium seemed to form chloride complexes more readily. These finding may suggest a difference in the initial mode of occurrence of these 2 elements (Fuchs and Rose 1974; Coker et al. 1991) or preferential leaching of Pd relative to Pt during decomposition of the bedrock (Wood and Vlassopoulos 1990).

Grain sizes of material sampled have also been found to play an important role in geochemical analysis for Pt, Pd, and Au. The majority of previous studies (Dilabio 1988; Fletcher 1988; Fuchs and Rose 1974; Wood and Vlassopoulos 1990) have shown that in weathered material, gold and PGEs are most abundant in the fine sediment sizes (- 63 μm) which could reflect the original grain size of the metals (Wood and Vlassopoulos 1990). These metals may also be in abundance within the - 63 μm grain size because of the high cation exchange capacity within this size fraction (Fuchs and Rose 1974). Fine fraction geochemistry (- 63μm) also puts somewhat of a control on the nugget effect for mineral grains, such as gold and PGMs, because samples with low grain counts can yield anomalous values if grains of such precious metals are large.

SOIL PROVENENCE

Of relevance to the present study is the question of whether the components of sampled soils have been derived from a proximal source. Pebble lithologies were examined and showed a general correlation with regional bedrock lithologies. Within the 2 case study areas, a relatively large portion of the pebbles were mafic intrusive and mafic extrusive in origin corresponding with underlying bedrock lithology. As well anomalous (Pt,Pd) soil samples collected within the sampling grid correlate with anomalous PGEs in bedrock underneath. This indicates that at least a significant portion of the samples within the case study sites were derived from mineralized River Valley bedrock.

PLATINUM AND PALLADIUM GEOCHEMISTRY

The average concentrations of Pt and Pd in bedrock within the Dana Lake zone, as reported by Pacific North West Capital Corp. is 2400 ppb (Pt+Pd+Rh) (Barr 1999). Pt and Pd contents within C-horizon tills, B-horizon soils and humus at Dana Lake show a direct relationship to adjacent bedrock mineralization, whereas, samples collected outside of the study areas generally do not show elevated Pt and Pd values. Many samples within the Dana Lake and Azen Creek zone contain Pt and Pd significantly higher than the detection limit. These all overlie the River Valley intrusion where elevated Pt and Pd values have been reported (Easton and Hrominchuk 1999; Hrominchuk 1999; Barr 1999).

Preliminary results from samples taken from the River Valley intrusion containing Pt and Pd above background levels show Pt/Pd ratios close to 1. Within highly mineralized samples, Pt/Pd ratios are closer to 0.3-0.4 (Easton and Hrominchuk 1999, J. Hrominchuk, personal communication, Ontario Geological Survey, 2000). Pt/Pd ratios in anomalous soil samples (B-, C-horizon and Humus) overlying the River Valley intrusion are generally lower than in the River Valley rocks themselves.

C-horizon till

Platinum concentrations within C-horizon soils range from not detected to 9 ppb with one sample reaching 218 ppb. Platinum geochemistry was plotted (Figures 13 and 14) where values above the 95th percentile were considered anomalous for the sampling area. Precision for this element was high (+/- 7ppb) therefore all values below the 95th percentile cannot be considered with any confidence.

Platinum concentrations are elevated within the case study areas compared to other parts of the sampling grid. The Dana Lake zone shows elevated levels of Pt in C-horizon till samples taken above mineralized bedrock (average value = 8 ppb), as well as up and down ice from mineralized bedrock (99-NPT-132, 99-NPT-139, 99-NPT-146, 99-NPT-152, 99-NPT-136, 99-NPT-161) (Figure 14). Down ice from the mineralized zones, west of Dana Lake, is a topographic low. This slope may affect post-glacial hydromorphic weathering of the materials or grains in the till. Within the Azen Creek zone, only one sample (99-NPT-169) showed anomalous values of Pt (7.6 ppb). Regionally, 2 samples show anomalous Pt concentrations similar or greater than the anomalous concentrations observed within the Dana Lake and Azen Creek case study areas. Samples 99-NPT-051 and 99-NPT-058 show Pt values of 11.3 ppb and 9.0 ppb, respectively. Samples surrounding these anomalies do not show elevated levels of Pt and Pd. Metasedimentary and gneissic bedrock underlie these regional sample sites (Figure 13).

Palladium concentrations within C-horizon till samples ranges from not detected to 181.1 ppb (typically < 5 ppb). As with Pt, the 2 case study areas show distinctly anomalous Pd values compared to the rest of the sampling grid (Figure 15). The Dana Lake zone shows anomalous Pd values above mineralized bedrock as well as up and down ice from the mineralized zones (99-NPT-161, 99-NPT-136, 99-NPT-132, 99-NPT-146, 99-NPT-158). A highly anomalous sample (99-NPT-146; 181.1 ppb) also occurs within the Dana Lake area within a topographic low (Figure 16). This is probably due to down-ice mechanical (glacial) transport of material derived from up-ice mineralized zones and deposited within a lee side cavity. At Azen Creek, 2 samples show anomalous Pd values (99-NPT-167 and 99-NPT-169). These samples are located above and down ice from mineralized bedrock (Figure 16). Regionally, only one sample (99-NPT-051) shows an anomalous value of Pd (7.7 ppb). This sample, also enriched in Pt, was not collected over River Valley intrusive rocks and no other samples surrounding it contain anomalous Pt or Pd values. The source for Pt and Pd is unknown.

Platinum/Palladium ratios of 2 samples at the Dana Lake case study correlate with highly anomalous bedrock ratios of 0.3 to 0.4 reported by Easton and Hrominchuk (1999) (99-NPT-136 (0.3), 99-NPT-158 (0.4)). Other samples at Dana Lake (99-NPT-132, 99-NPT-139, 99-NPT-146, 99-NPT-152, 99-NPT-161,) display Pt enrichment relative to Pd (Figures 14 and 16). Within the Azen Creek study area, 3 samples (99-NPT-169 and 99-NPT-167) show enrichment in Pd relative to Pt. In sample 99-NPT-169, there is only a slight enrichment where the ratio nears 1 corresponding to above background values in bedrock as reported by Easton and Hrominchuk (1999). The two samples collected at site 99-NPT-167 (at different sample depths) display Pd enrichment (9:1 and 13:1) reflecting highly anomalous bedrock ratios (Easton and Hrominchuk 1999). Regionally the Pt/Pd ratio for sample 99-NPT-051 (0.7) corresponds with bedrock ratios obtained from the Dana Lake mineralized zone.

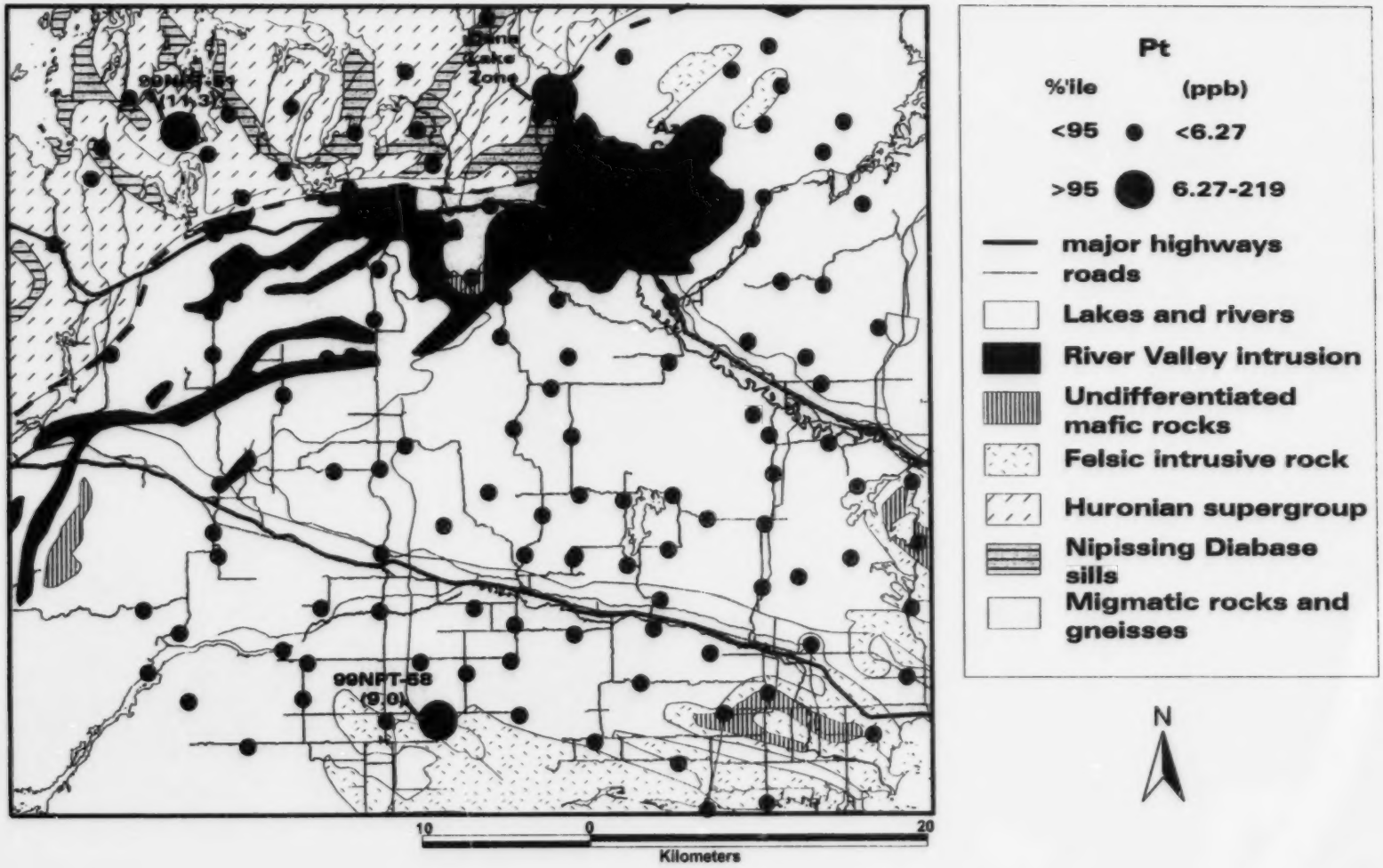


Figure 13: Regional Distribution of Platinum in C-horizon till.

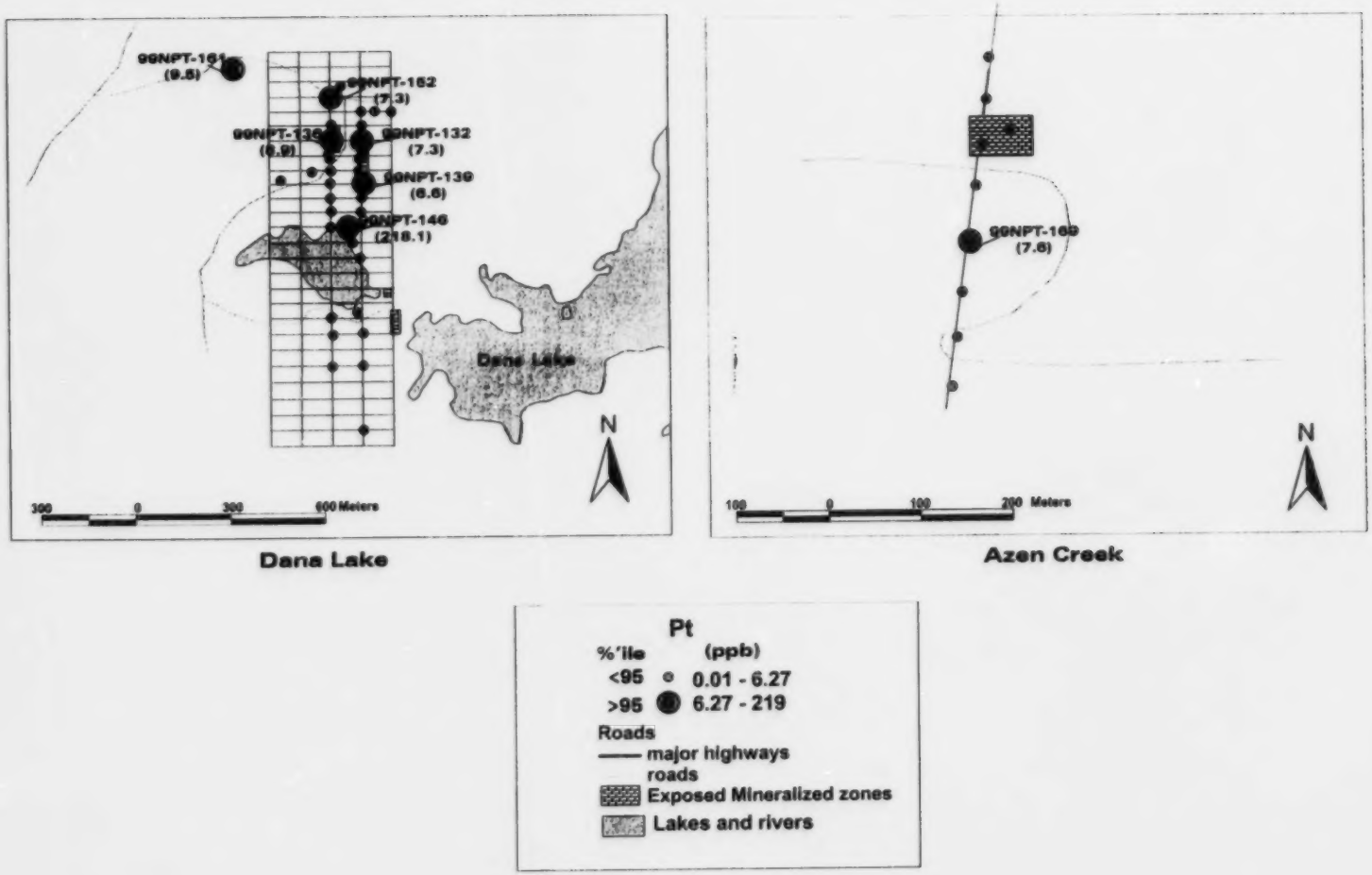


Figure 14: Distribution of Platinum in C-horizon till at the Dana Lake and Azen Creek case study sites.

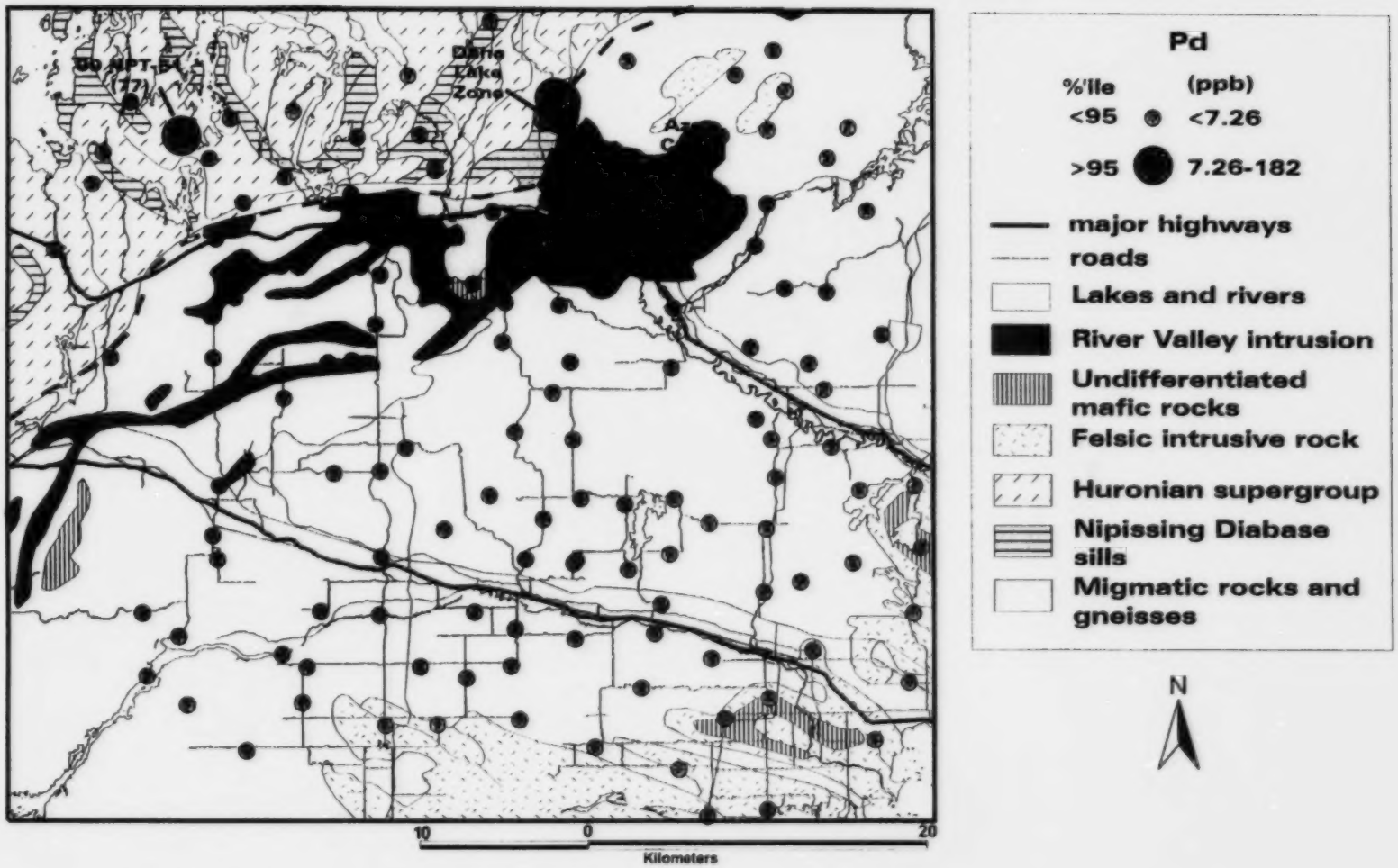


Figure 15: Regional distribution of palladium in C-horizon till.

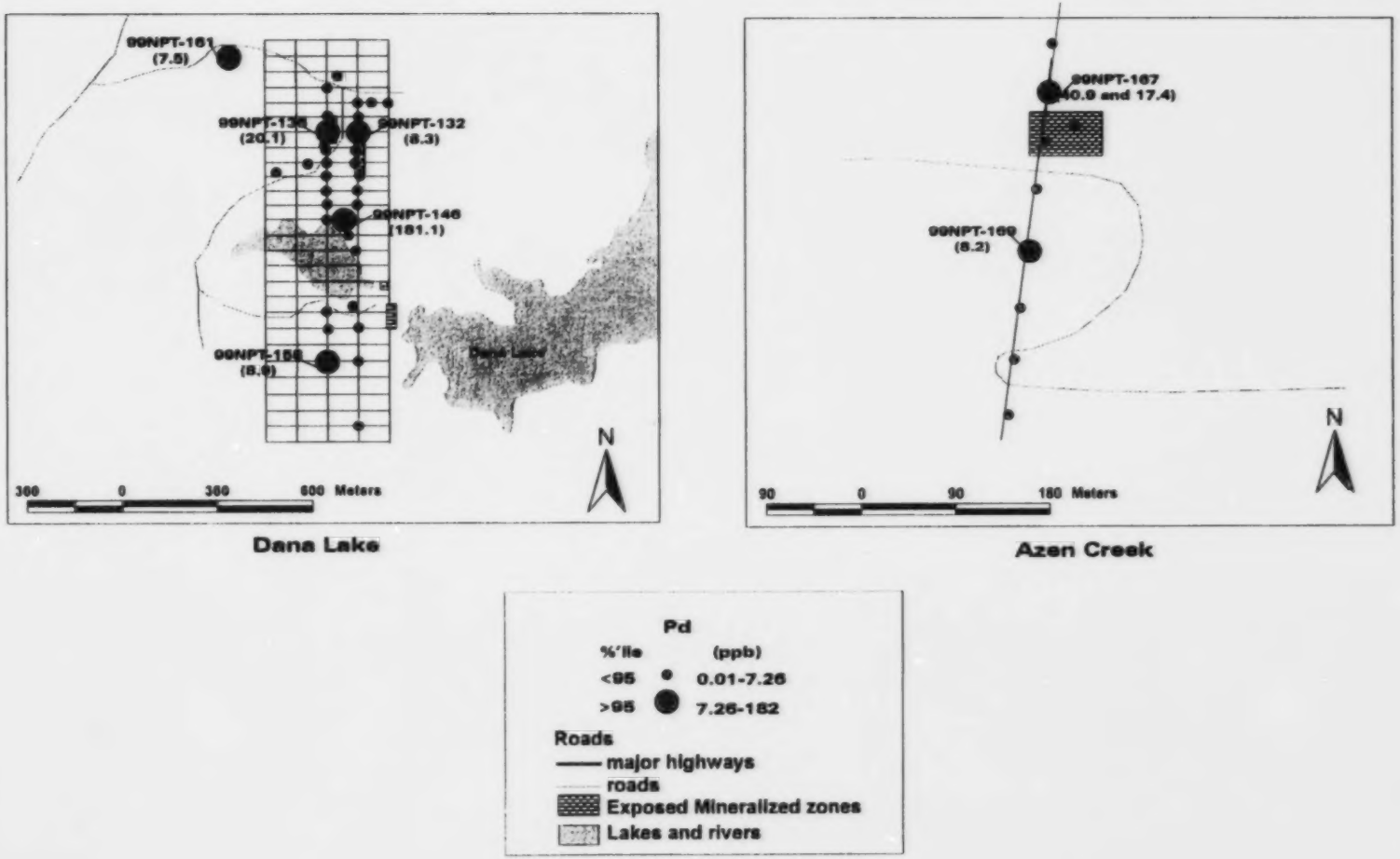


Figure 16: Distribution of palladium in C-horizon till at the Dana Lake and Azen Creek case study sites.

B-horizon soils

Platinum concentrations in B-horizon soils range from not detected to 11.5 ppb (typically < 3ppb) (Appendix K1, this report). Only the 2 case study areas contain anomalous values of Platinum (Figures 17 and 18). At Dana Lake, samples down ice from the North and Road mineralized zones are enriched and Pt content increases towards Dana Lake (99-NPT-138, 99-NPT-142, 99-NPT-145, 99-NPT-148, 99-NPT-155, 99-NPT-158). Mechanical and chemical transport of soils and their mineralized pebbles and grains may cause this enrichment towards the topographic low. At Azen Creek, only one sample displays anomalous values of Pt (99-NPT-167). Pt concentrations at Azen Creek are lower than Pt concentrations observed at Dana Lake. This corresponds with platinum geochemistry observed in bedrock for both case study areas.

Case study sites are the only areas showing highly anomalous Pd values in B-horizon soils (Figure 19 and 20). At Dana Lake, Pd seems to be dispersed above and down ice from the exposed mineralized zones. The ratio between Pt and Pd in this area is very variable. Samples containing anomalous values of both Pd and Pt (99-NPT-145, 99-NPT-155, 99-NPT-156) do not indicate enrichment in either element. At Azen Creek, one sample show anomalous Pd values (99-NPT-167). Pd content within this sample is significantly lower than Pt (1:15).

Humus

Multiple sites within the study area, including the Dana Lake and Azen Creek case study areas, show anomalous values of Pt and Pd in humus (Figures 21 and 22). Generally, sites containing high Pd contain high Pt. At the Dana Lake case study site all but one sample (99-NPT-135) has Pt enrichment relative to Pd (Figures 23 and 24). Sample 99-NPT-135 was collected directly over bedrock, thus, the palladium rich signature of the bedrock might be affecting this trend. At the Azen Creek case study site this same trend occurs (Figures 23 and 24). Only one sample site (99-NPT-031) shows concentrations of Pd higher than Pt. However, this difference is very small and since Pt and Pd mineralization within this area is not as prominent as at Dana Lake their signatures may not be as evident in the humus. In the western part of the regional sampling grid, samples show elevated Pt/Pd content (99-NPT-076, 99-NPT-111, 99-NPT-112, 99-NPT-114, 99-NPT-115, 99-NPT-164, 99-NPT-165) (Figures 21 and 22). These elevated concentrations do not necessarily correspond with elevated Pt/Pd found in B-horizon soils or C-horizon tills.

High platinum and palladium concentrations in humus observed in the western part of the study area are possibly a result of pollution, generated by smelter activity several kilometers to the west, in Sudbury (Figures 21 and 22). Smelting and refining of Cu, Ni and PGE ores has and is currently taking place.

Humus samples show enriched Pt values relative to the other sampling media. Palladium does not seem to follow this trend; it is very irregular within all 3 sampling media. This is especially evident above the Dana Lake case study. This observation seems to indicate that humus concentrates Pt more easily than Pd in this area. This could be used as a method of biogeochemical exploration where humus containing highly anomalous platinum values would suggest the need for further investigation.

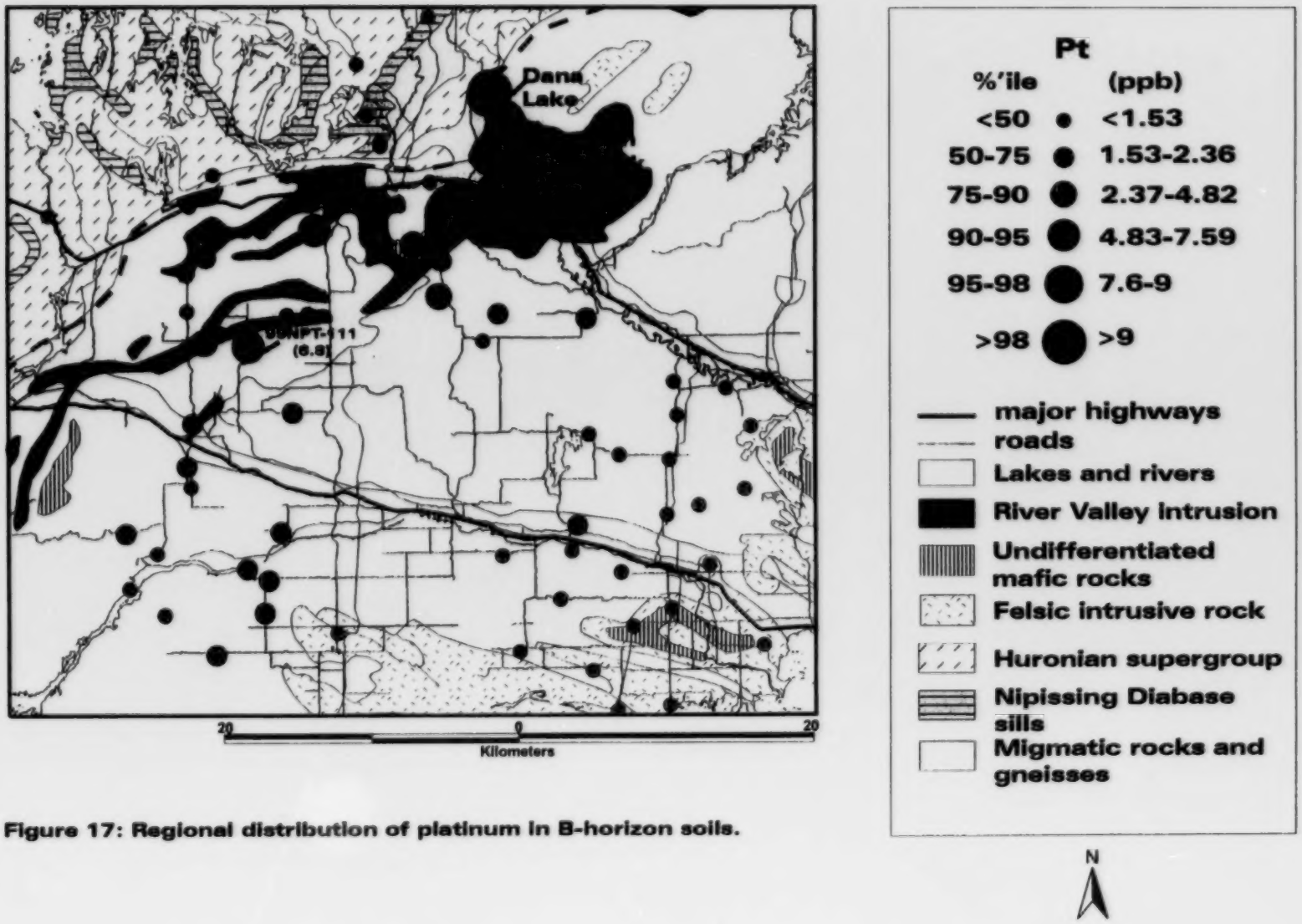
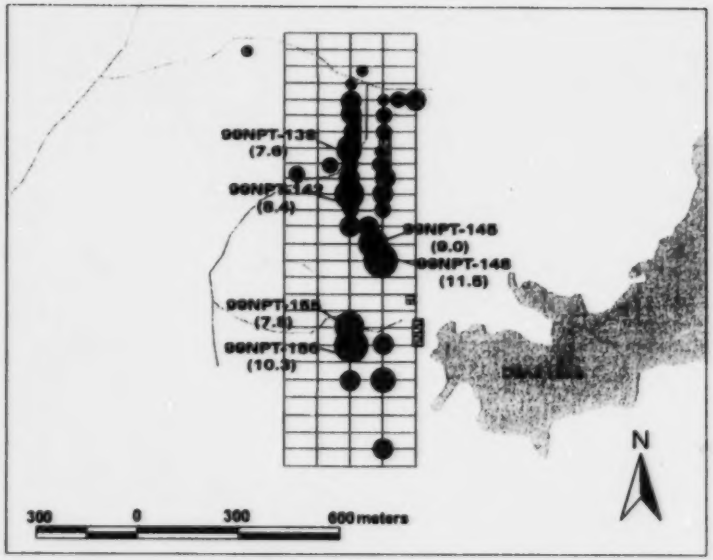
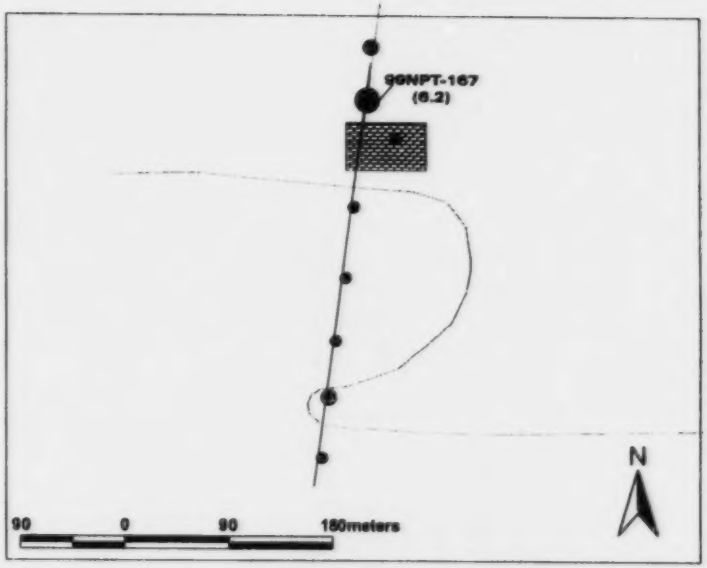


Figure 17: Regional distribution of platinum in B-horizon soils.



Dana Lake



Azen Creek

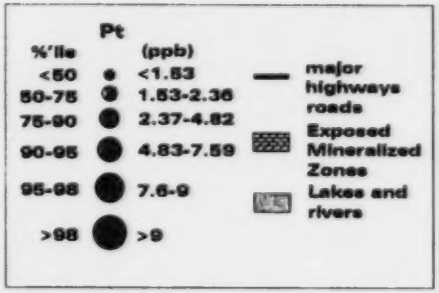


Figure 18: Distribution of platinum in B-horizon soils at the Dana Lake and Azen Creek case study sites.

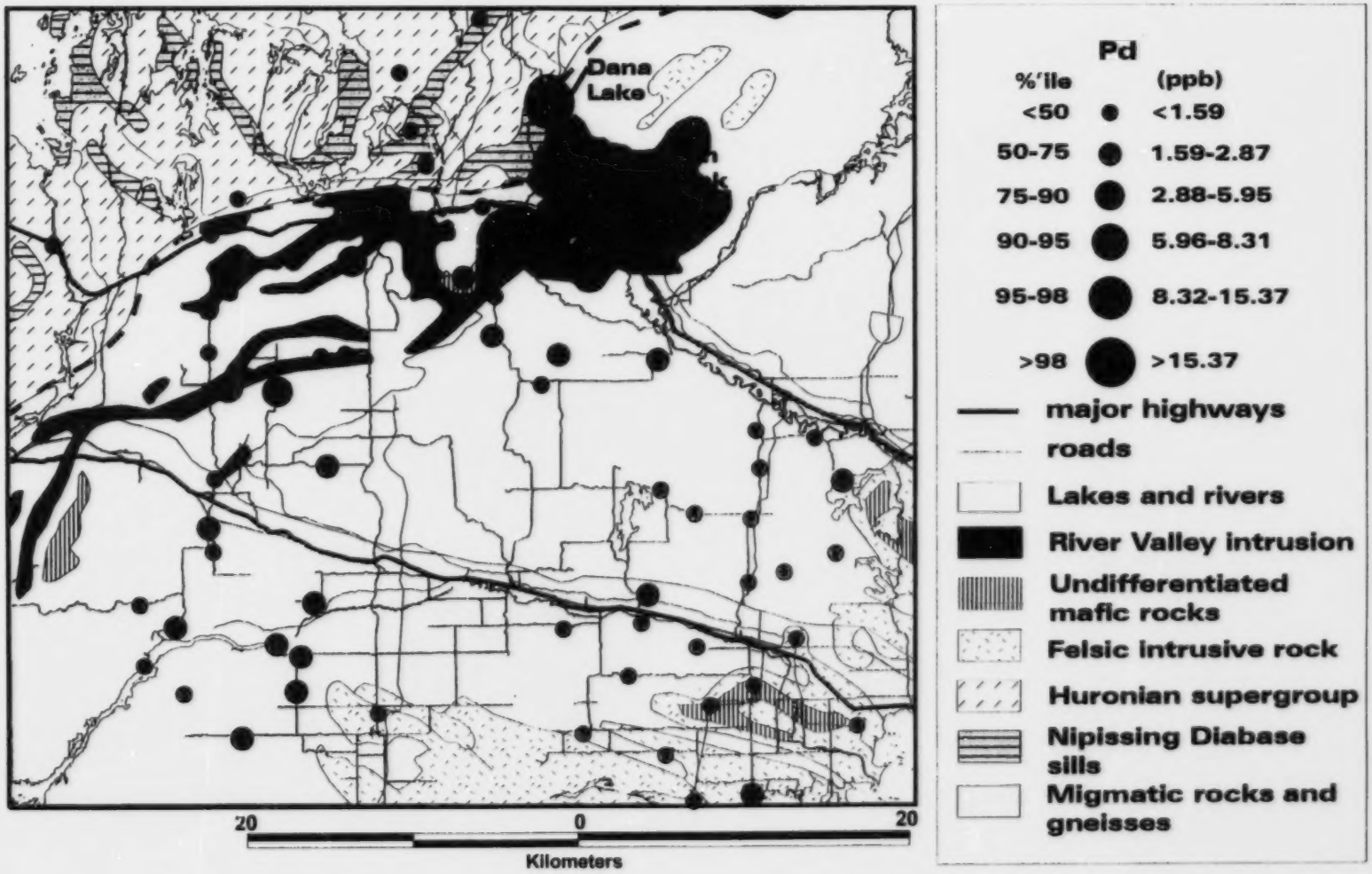
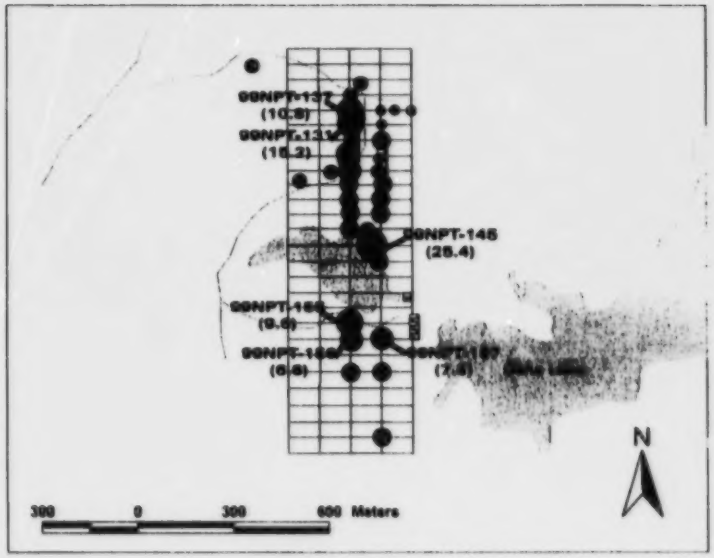
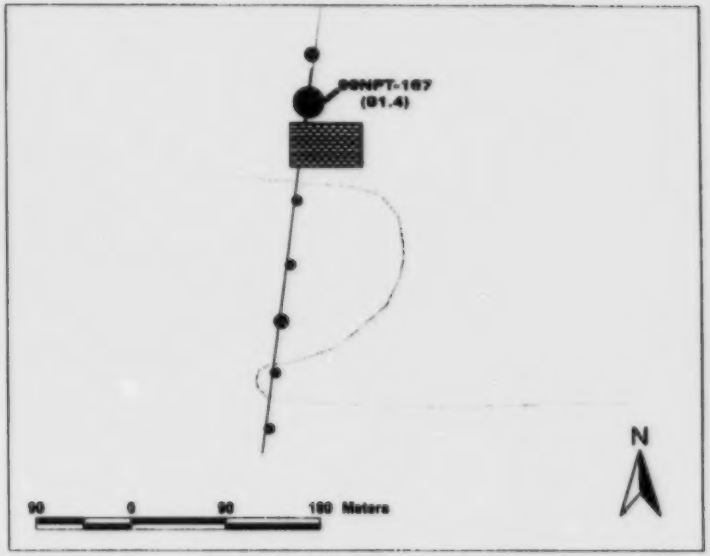


Figure 19: Regional distribution of palladium in B-horizon soil derived from till.



Dana Lake



Azen Creek

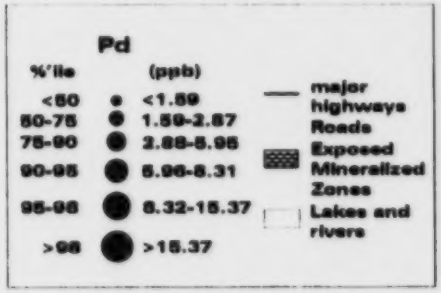


Figure 20: Distribution of palladium in B-horizon soils at the Dana Lake and Azen Creek case study sites.

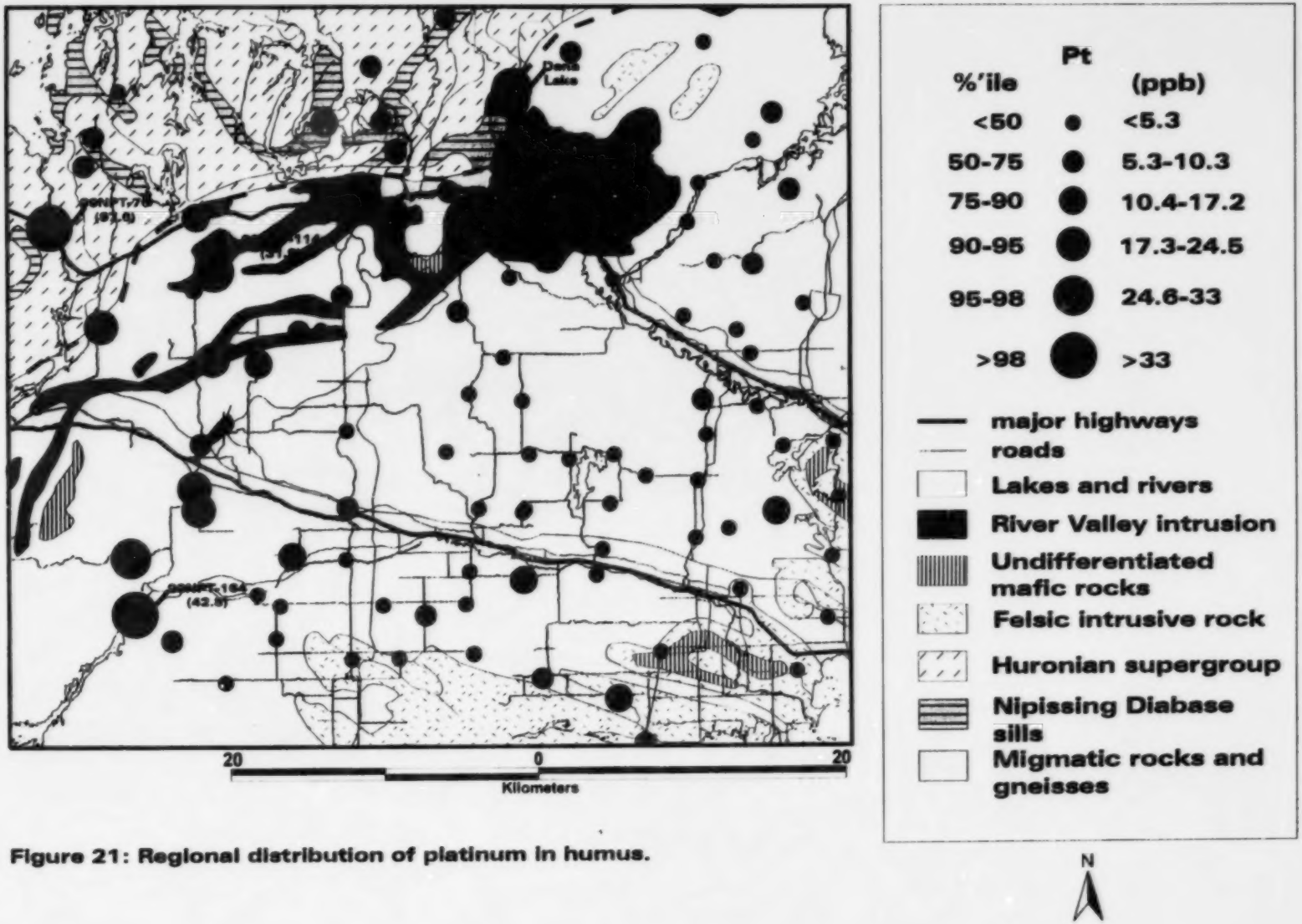


Figure 21: Regional distribution of platinum in humus.

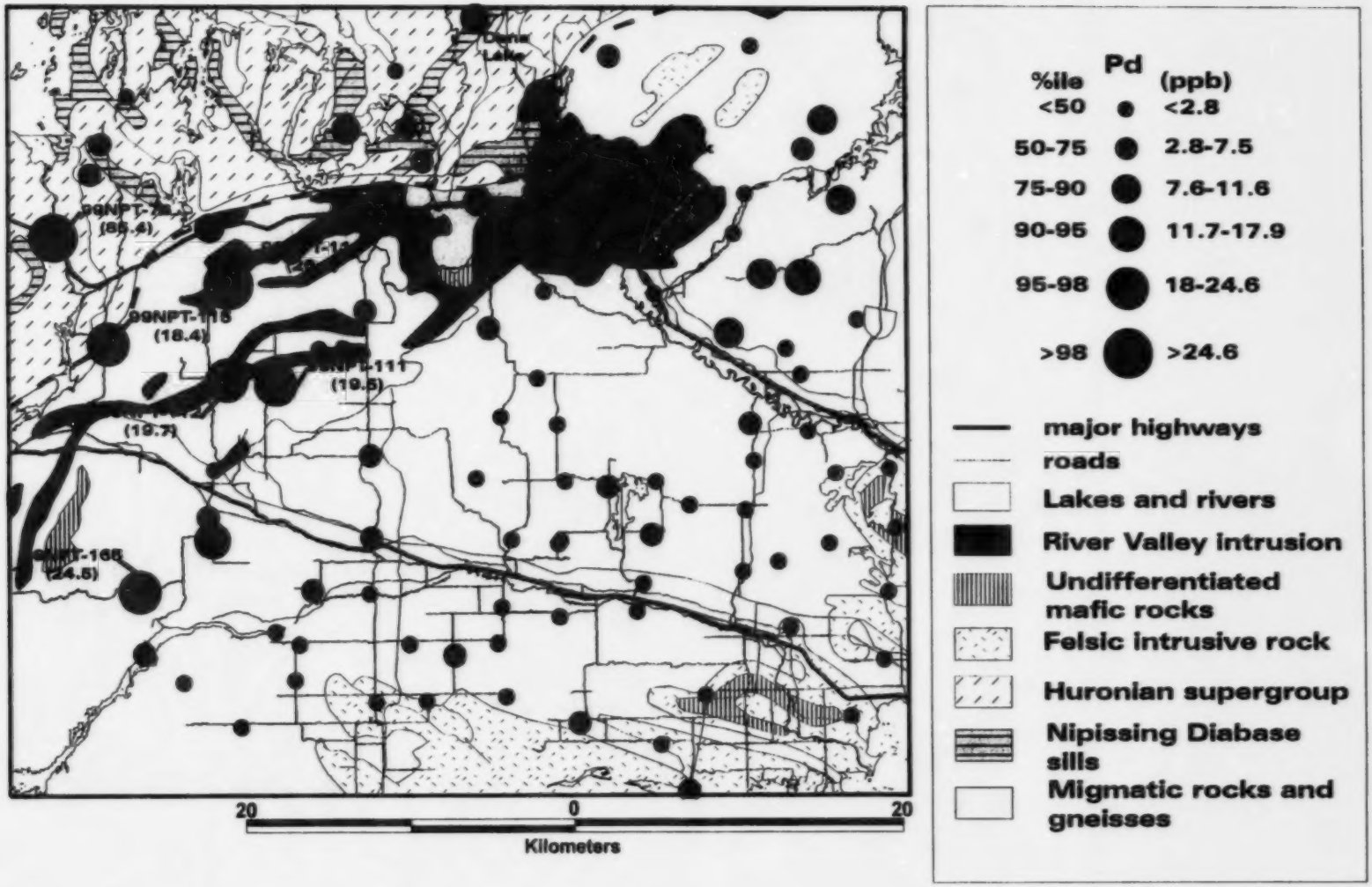
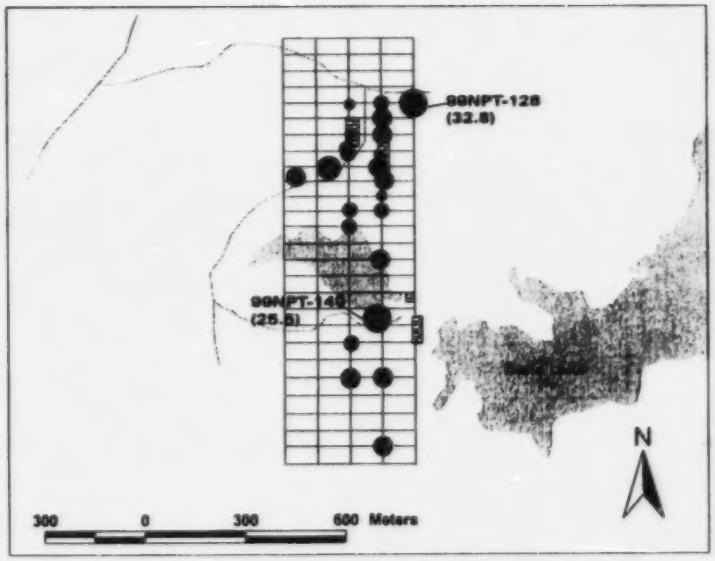
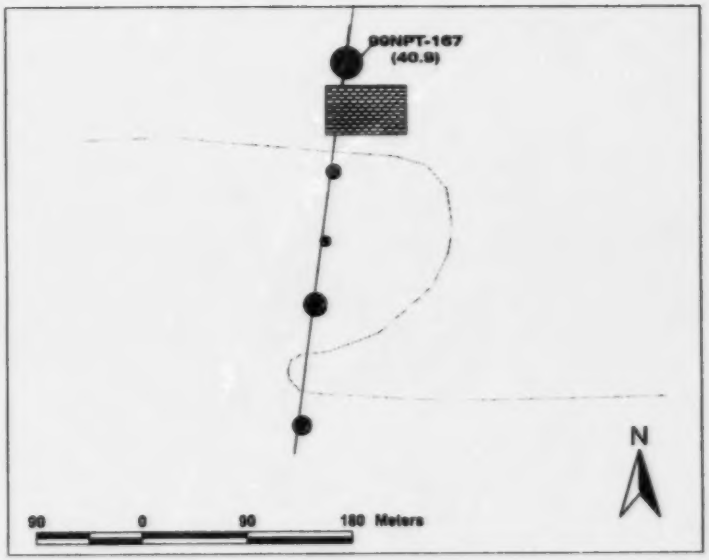


Figure 22: Regional distribution of palladium in humus.



Dana Lake



Azen Creek

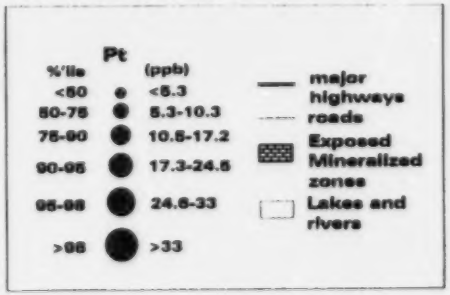


Figure 23: Distribution of platinum in humus at the Dana Lake and Azen Creek study sites.

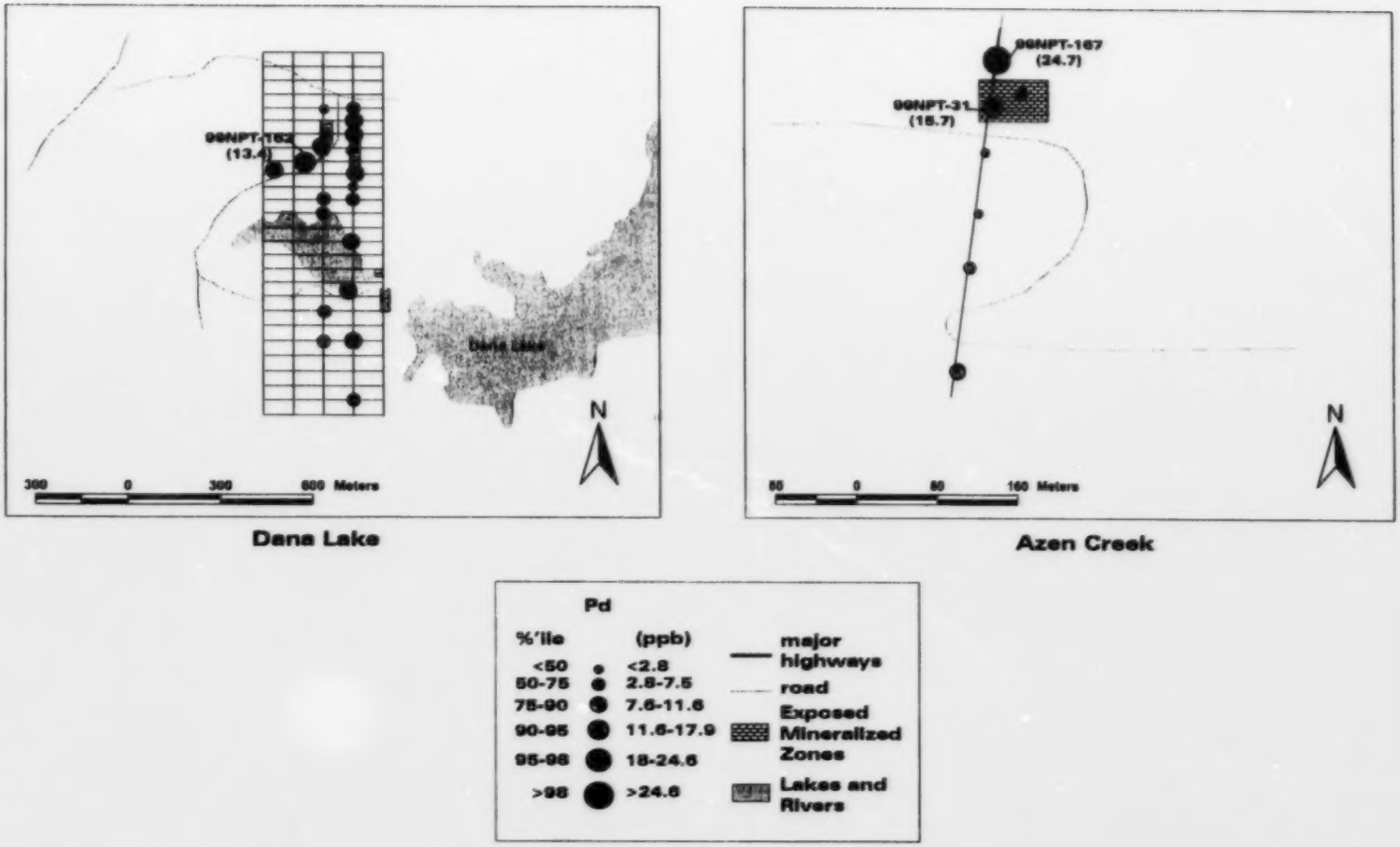


Figure 24: Distribution of palladium in humus at the Dana Lake and Azen Creek case study sites.

Pt/Pd results from non-ferromagnetic heavy minerals (C-horizon till)

Platinum and palladium concentrations within non-ferromagnetic heavy minerals range from not detected to 1014 ppb (Figures 25 and 26). Background values for both elements are approximately 5 ppb.

Three sites within the regional sampling grid show highly anomalous Pt/Pd concentrations (Figures 25 and 26). The Dana Lake and Azen Creek case study sites show most of the significant anomalies (Figures 27 and 28). At Dana Lake, anomalous samples range from 53 to 1014 ppb platinum (99-NPT-136, 99-NPT-141, 99-NPT-143, 99-NPT-149, 99-NPT-157, 99-NPT-160) and 85 to 872.5 ppb palladium (99-NPT-139, 99-NPT 140, 99-NPT-141, 99-NPT-142, 99-NPT-148, 99-NPT-149, 99-NPT-157, 99-NPT-159, 99-NPT-160) (Figures 27 and 28). Pt/Pd ratios within the Dana Lake area generally show palladium enrichment, however, it is very variable from sample to sample.

Within the Dana Lake case study area, palladium concentration seems to increase southward towards Dana Lake. Samples 99-NPT-149, 99-NPT-155, 99-NPT-156, 99-NPT-157 and all samples down ice from these sites show anomalous Pt/Pd values. This may be explained by 1) glacial transport of till from up-ice mineralized sites (North and Road zones); or 2) extended mineralization to the west from the South zone. At Azen Creek, one sample contains highly anomalous values of Pt and Pd (99-NPT-072) (Figures 27 and 28). However, this sample must be viewed with caution because it is sand and has not been subglacially deposited. Thus, provenance cannot readily be determined.

Sample 99-NPT-073, located south of the River Valley intrusion also contains highly anomalous Pt and Pd, 92 and 44 ppb respectively. Considering the similarity in signature to samples collected in the case study sites, this sample area should be considered for further investigation.

In summary, results indicate that B-horizon soils, C-horizon subglacial tills and non-ferromagnetic heavy minerals can be used for Pt and Pd exploration. Values observed within the non-ferromagnetic heavy mineral samples are significantly higher than values observed within C-horizon tills, B-horizon soils and humus, however, costs for sample analysis of the non-ferromagnetic and ferromagnetic heavy minerals are also significantly higher. Ferromagnetic heavy minerals may also show this signature, however, very low quantities of ferromagnetics within almost all samples collected as part of this study prevented analysis for Pt and Pd.

GOLD

Geochemical values for gold shows a similar, though not direct, relationship with platinum and palladium geochemical values within the different surficial media.

The highest gold values are observed within non-ferromagnetic heavy minerals. Gold geochemistry ranges from 2 ppb to 1268 ppb within this media (Figure 29). The highest values are generally concentrated within the northeastern part of the study area, including the Dana Lake case study area, where gold within the underlying bedrock has been reported (Barr 1999). Gold within C-horizon till samples also show enrichment in the northeastern part of the sampling grid (Figure 30). C-horizon tills collected from the Dana Lake case study area show anomalous gold, as well as 2 regional samples (99-NPT-006, 99-NPT-011) (Figure 31). B-horizon samples also show anomalous gold values within the Dana Lake case study area (Figures 32 and 33). Poor

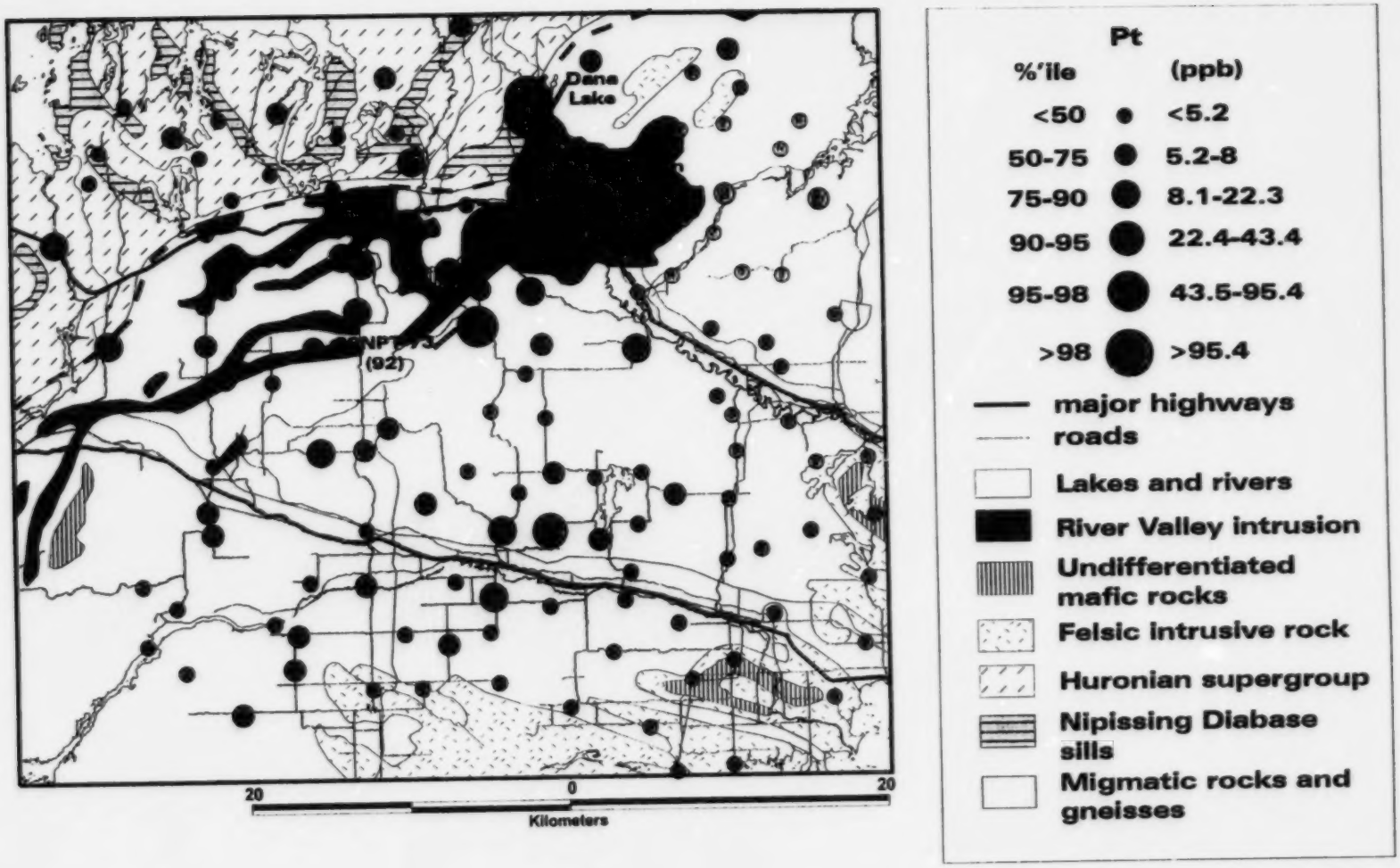


Figure 25: Regional distribution of platinum in non-ferromagnetic heavy minerals.

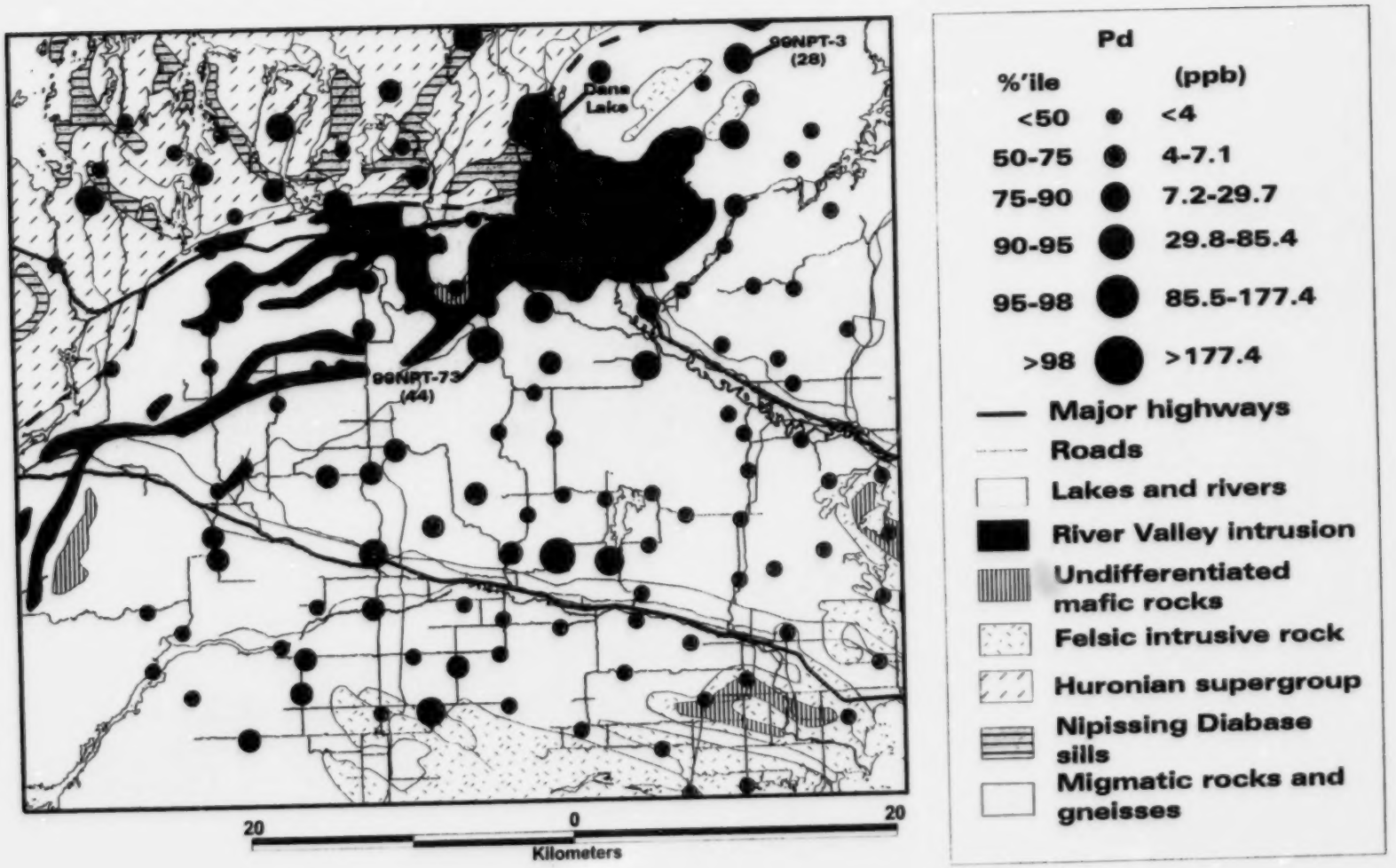


Figure 26: Regional distribution of palladium in non-ferromagnetic heavy minerals.

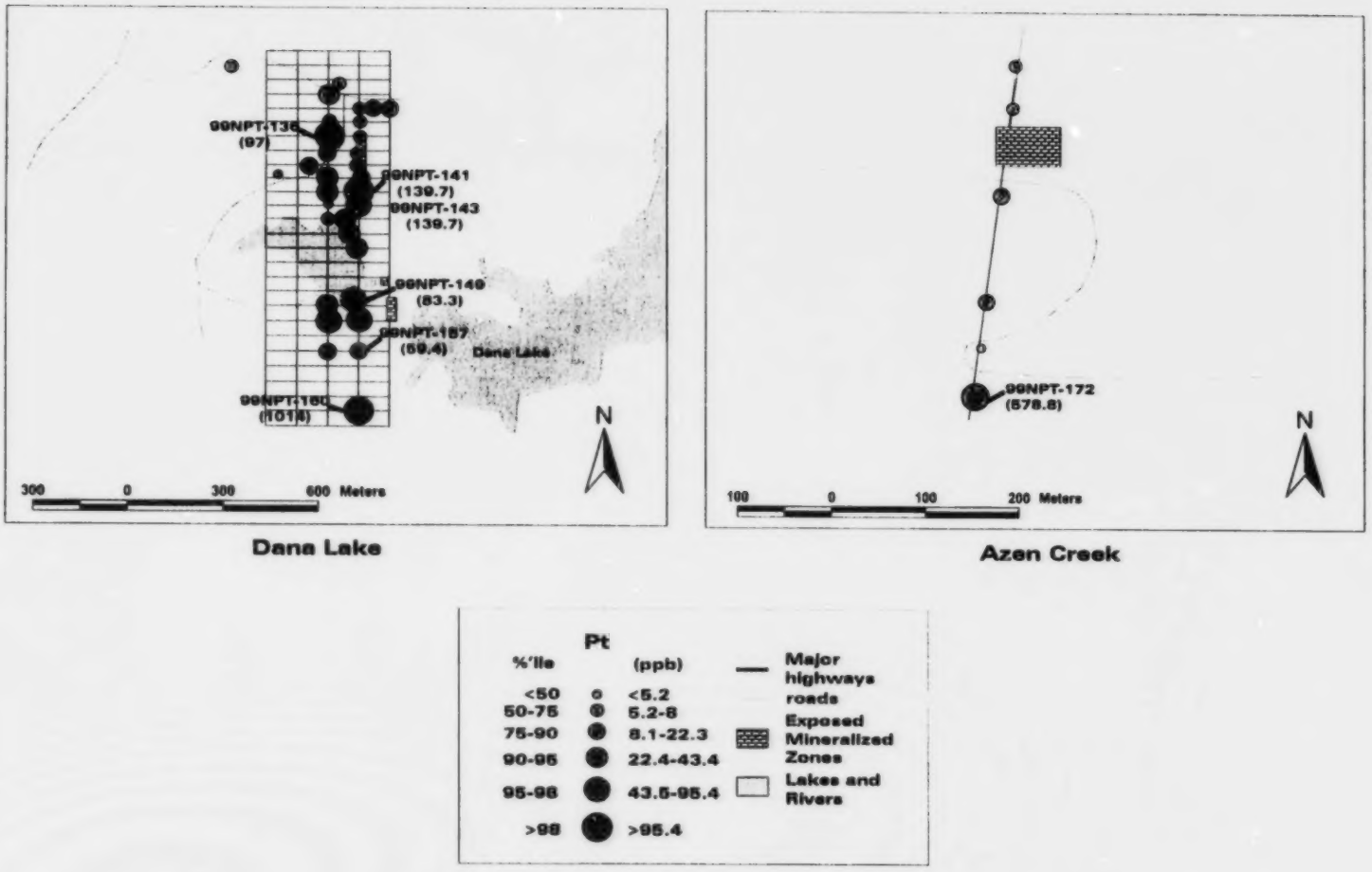
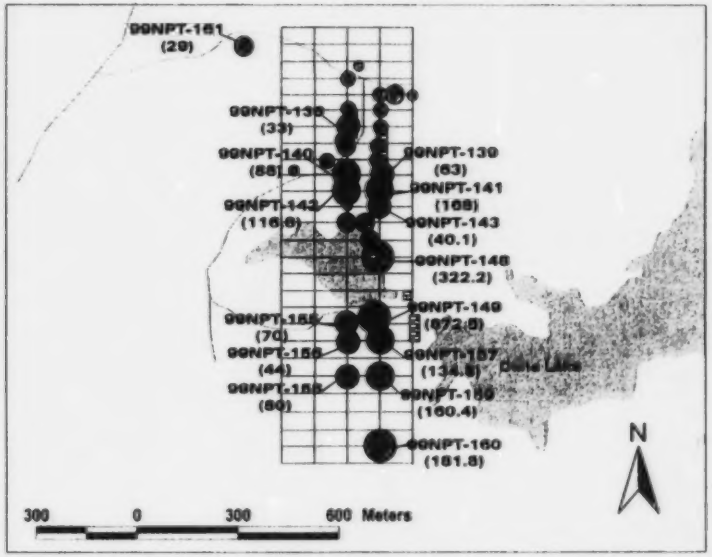
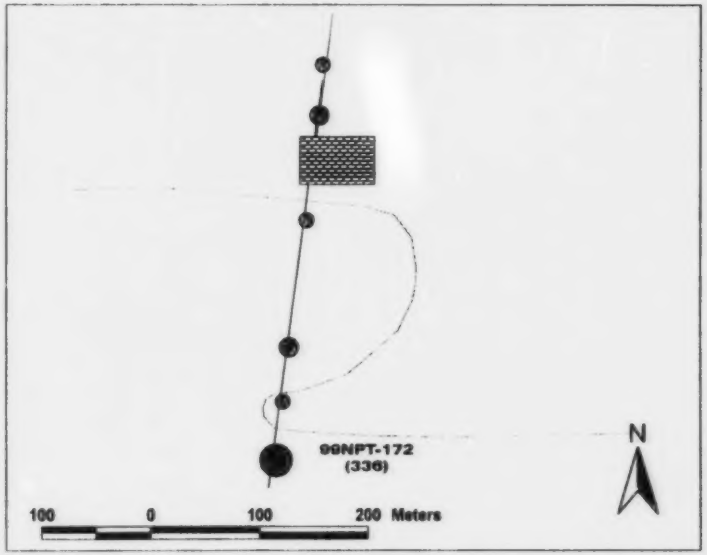


Figure 27: Distribution of platinum in non-ferromagnetic heavy minerals at the Dana Lake and Azen Creek case study sites.



Dana Lake



Azen Creek

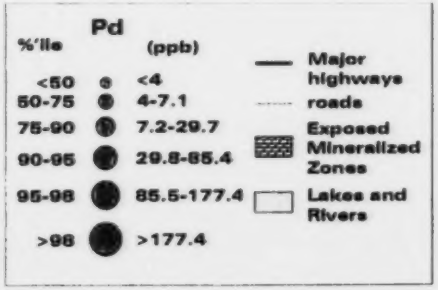


Figure 28: Distribution of palladium in non-ferromagnetic heavy minerals at the Dana Lake and Azen Creek case study sites.

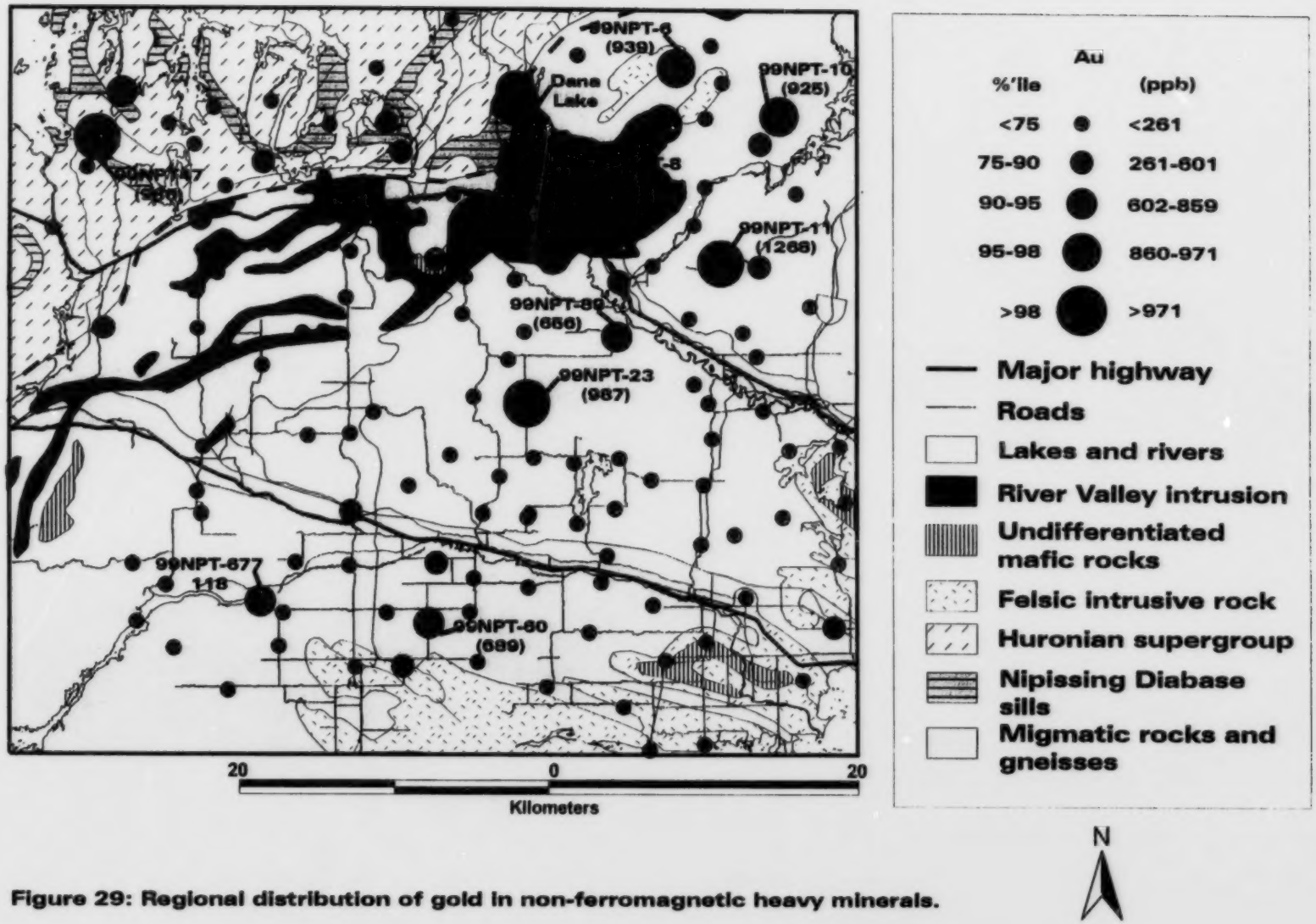


Figure 29: Regional distribution of gold in non-ferromagnetic heavy minerals.

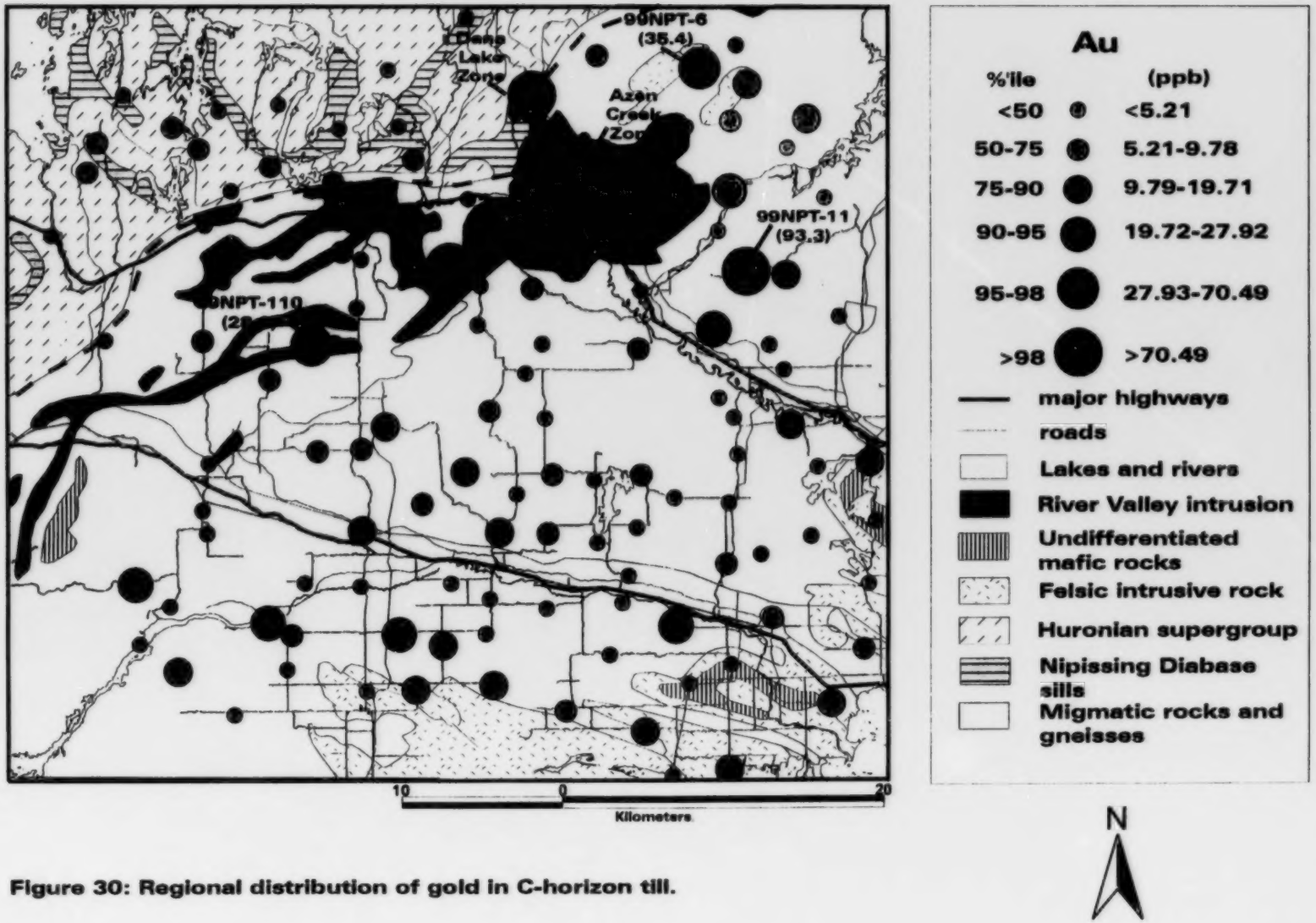
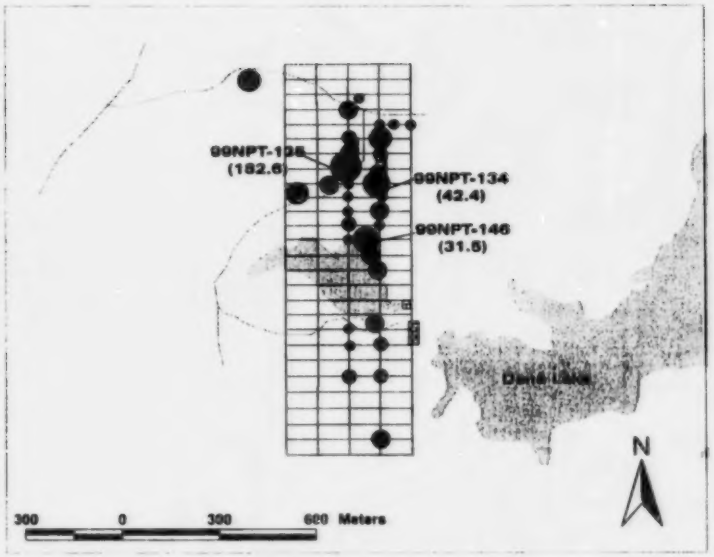
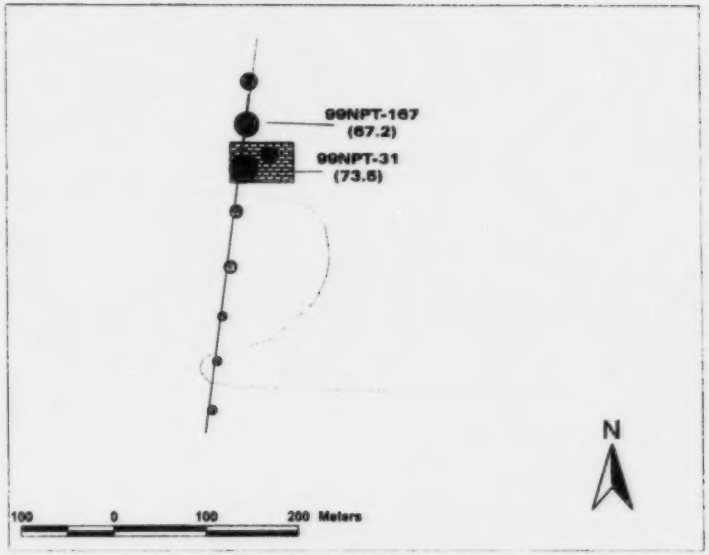


Figure 30: Regional distribution of gold in C-horizon till.



Dana Lake



Azen Creek

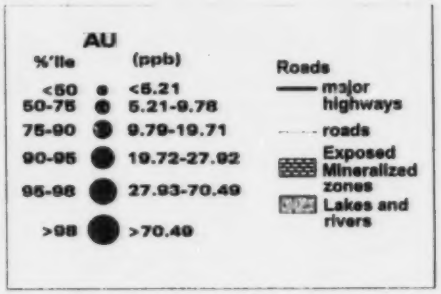


Figure 31: Distribution of gold in C-horizon till at the Dana Lake and Azen Creek case study sites.

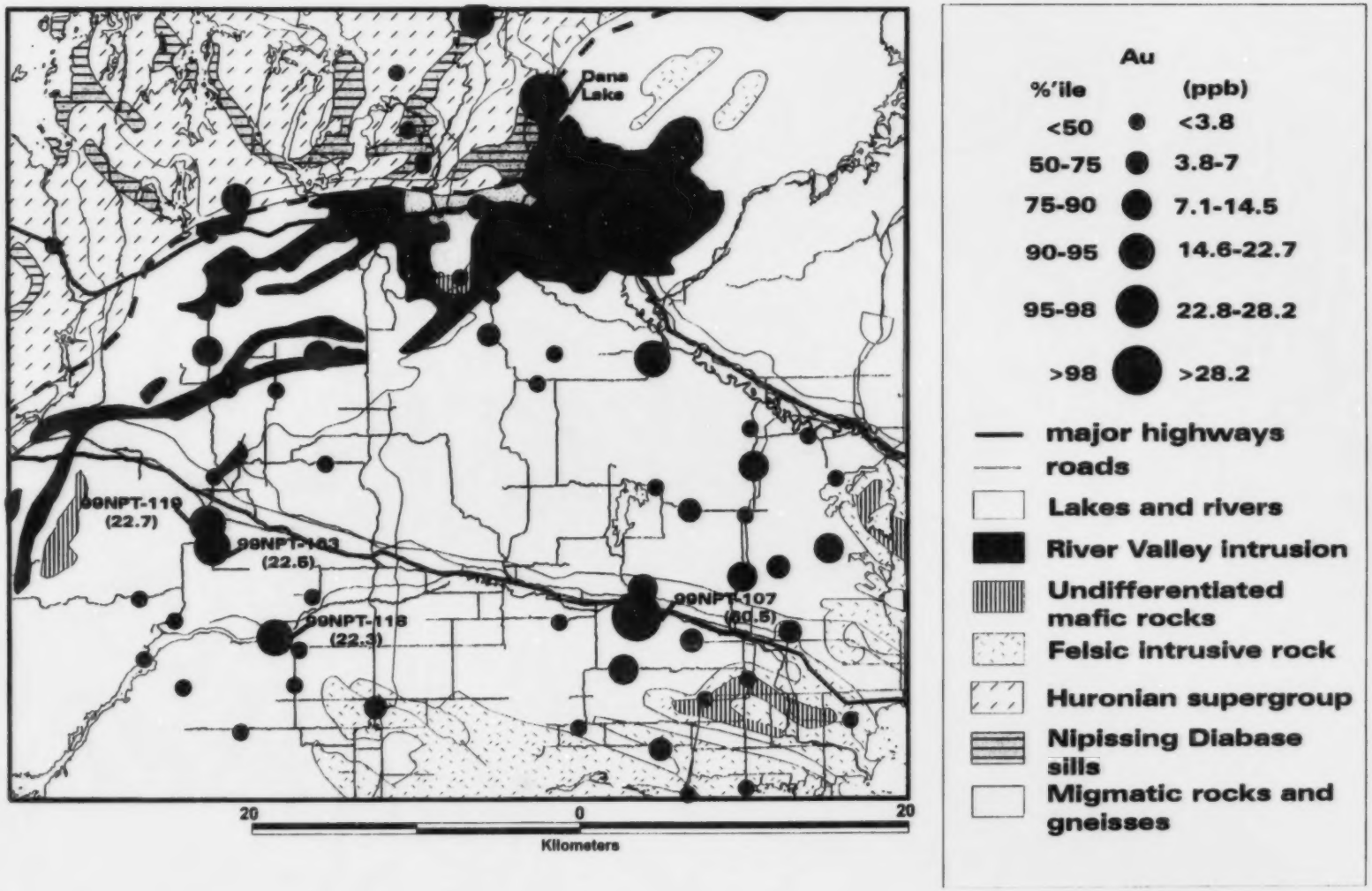
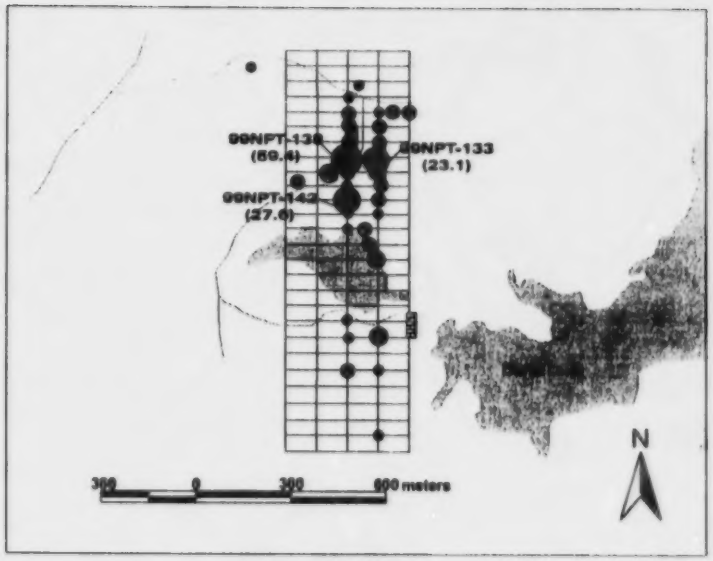
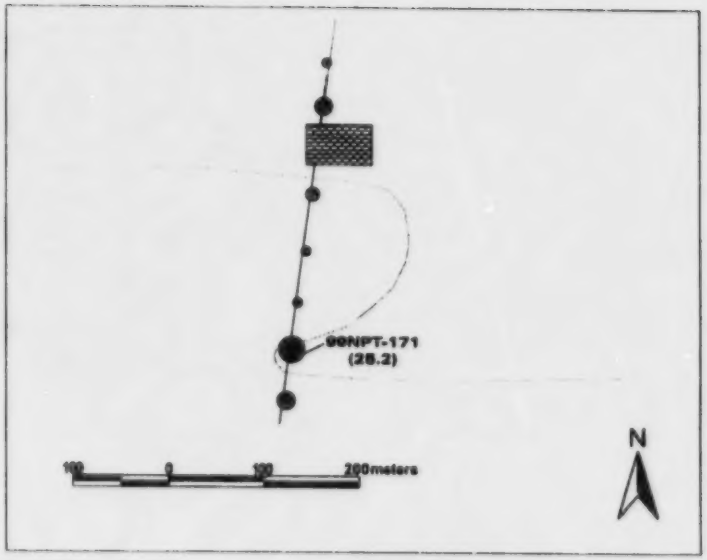


Figure 32: Regional distribution of gold in B-horizon soils



Dana Lake



Azen Creek

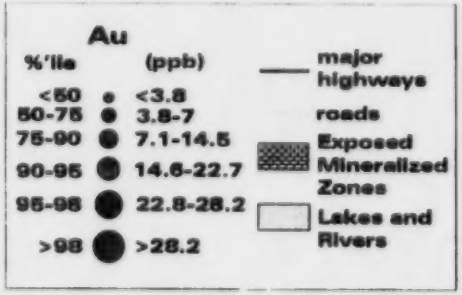


Figure 33: Distribution of gold in B-horizon soils at the Dana Lake and Azen Creek case study sites.

analytical precision (+/- 15 ppb) for gold in humus makes it difficult to assess gold values with confidence.

COPPER-NICKEL

Copper mineralization has been reported within bedrock at the Dana Lake and Azen Creek study areas (2X and 4X above background, i.e., between 70 to 140 ppm). Generally, the Azen Creek area has higher Cu than the Dana Lake area (Easton and Hrominchuk 1999; Barr 1999). Only one sampling media showed analytical results following this trend. The non-ferromagnetic heavy mineral fraction of the C-horizon tills shows significant Cu enrichment (>1000 ppm) directly above bedrock within the Azen Creek case study area and slightly above background Cu within the Dana Lake case study area (30 to 40 ppm) (Figure 34). Other samples within the regional study area containing Cu greater than 1000 ppm include samples 99-NPT-014, 99-NPT-015 and 99-NPT-071. These may be possible exploration targets.

Cu values within the ferromagnetic heavy minerals show a Cu enrichment in samples from the northern part of the study area. Copper within this area may be derived from the underlying Nippissing diabase sills (Figure 35). Humus also shows anomalous Cu values in the western part of the study area (Figure 36). Like Pt and Pd, this may be the result of airborne fallout from Sudbury smelters.

Regionally, nickel anomalies within till samples somewhat correlate with Cu, Pt or Pd anomalies. Within the case study areas, nickel is relatively anomalous with respect to Ni values in the rest of the regional sampling grid. Other trends observed include Ni anomalies within humus samples. These anomalies seem to be concentrating within the western part of the study area where they may be a result of Sudbury derived airborne fallout.

Pt, Pd, Au, Cu AND Ni RESULTS

Analytical results for Pt, Pd and Au in C-horizon till, B-horizon soils, humus and non-ferromagnetic heavy mineral are presented in Appendix K1 and K2, this report. Data for Au, Cu, Ni and a variety of other elements analyzed is summarized in Tardif (2000, Appendix K).

In general, platinum, palladium and gold values are more elevated in all media within the case study areas as compared to the rest of the regional sampling grid. This is also the case for Cu and Ni. These results indicate that surficial sampling can detect Au, Pt, Pd, Cu and Ni anomalies. The non-ferromagnetic heavy minerals yielded the highest anomaly to background ratio for Pt, Pd and Au in this study.

Pt and Pd anomalies found outside the cases study areas may represent: 1) genuine anomalies associated with different mineralization styles; 2) false anomalies due to analytical and sampling problems; or 3) displaced anomalies related to the River Valley occurrence by differential mechanical or chemical mobility of various metals (Cook et al. 1992).

The difference in behaviour between Pt and Pd within all sampling media could reflect an initial mechanical (glacial) dispersal for both elements and subsequent hydromorphic processes transporting the more mobile Pd and concentrating less mobile Pt as suggested by Fuchs and Rose (1974), Wood and Vlassopoulos (1990), and Cook et al. (1992). However, additional work is required in order to substantiate this hypothesis.

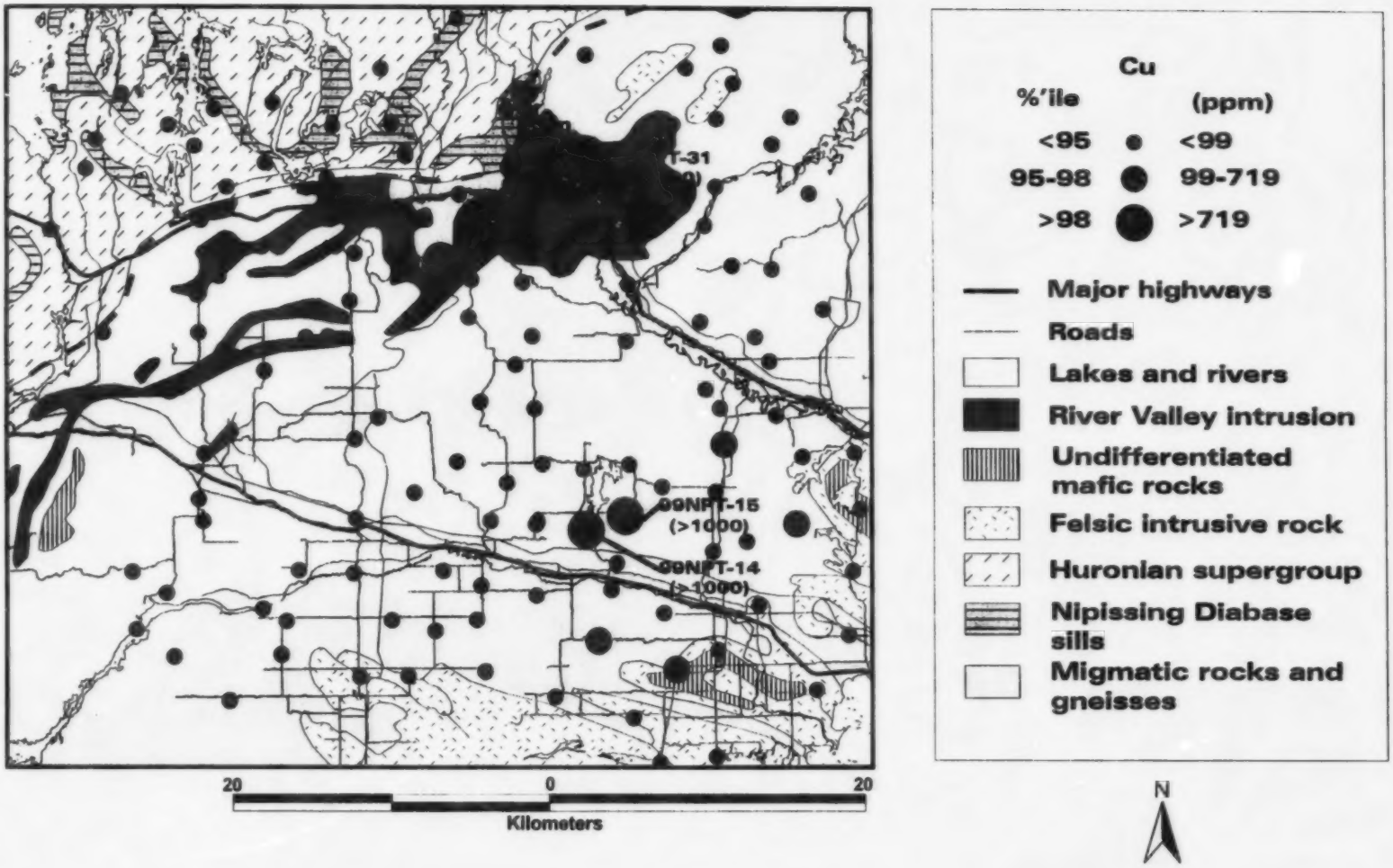


Figure 34: Regional distribution of copper in non-ferromagnetic heavy minerals.

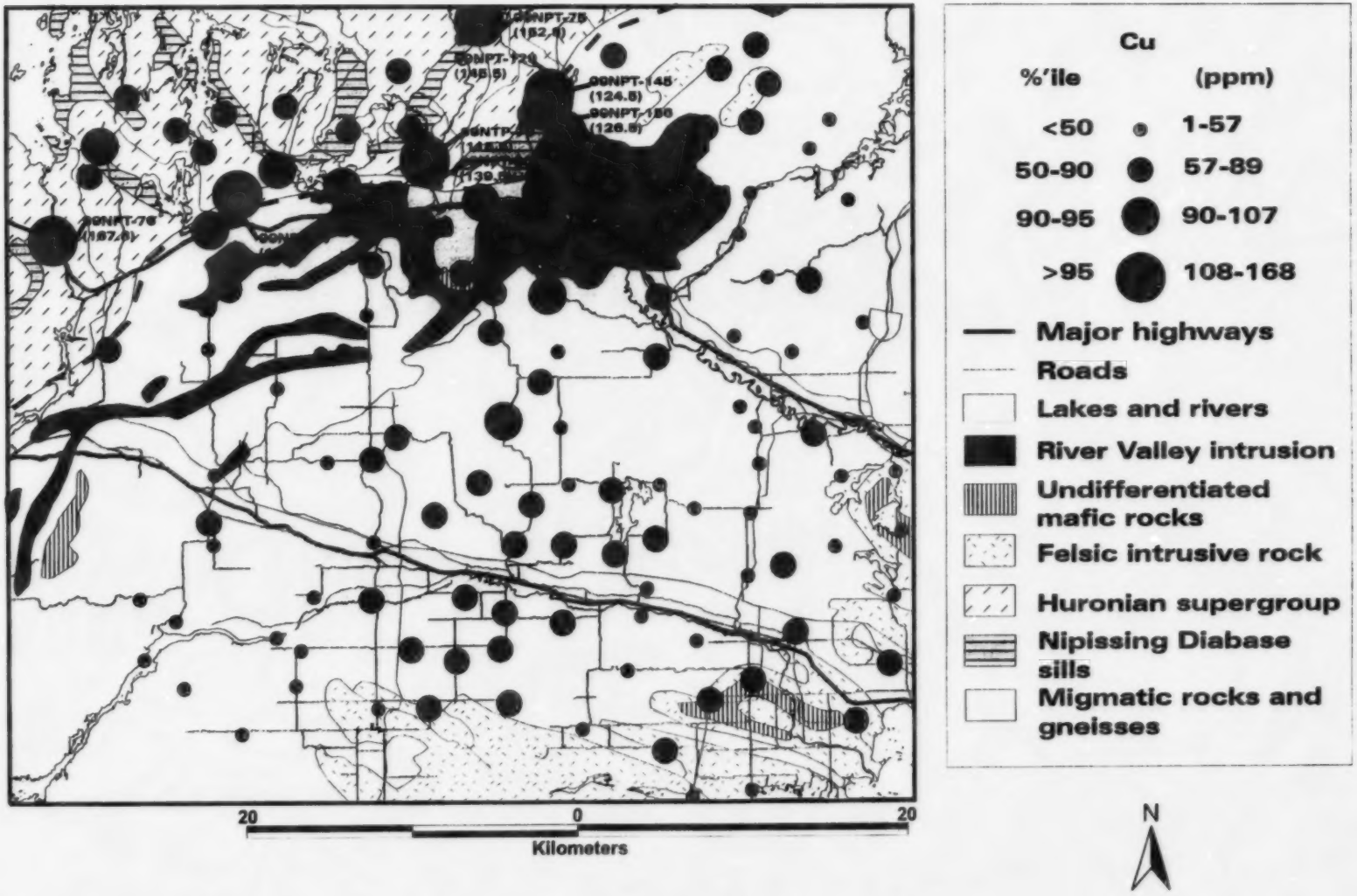


Figure 35: Regional distribution of copper in ferromagnetic heavy minerals.

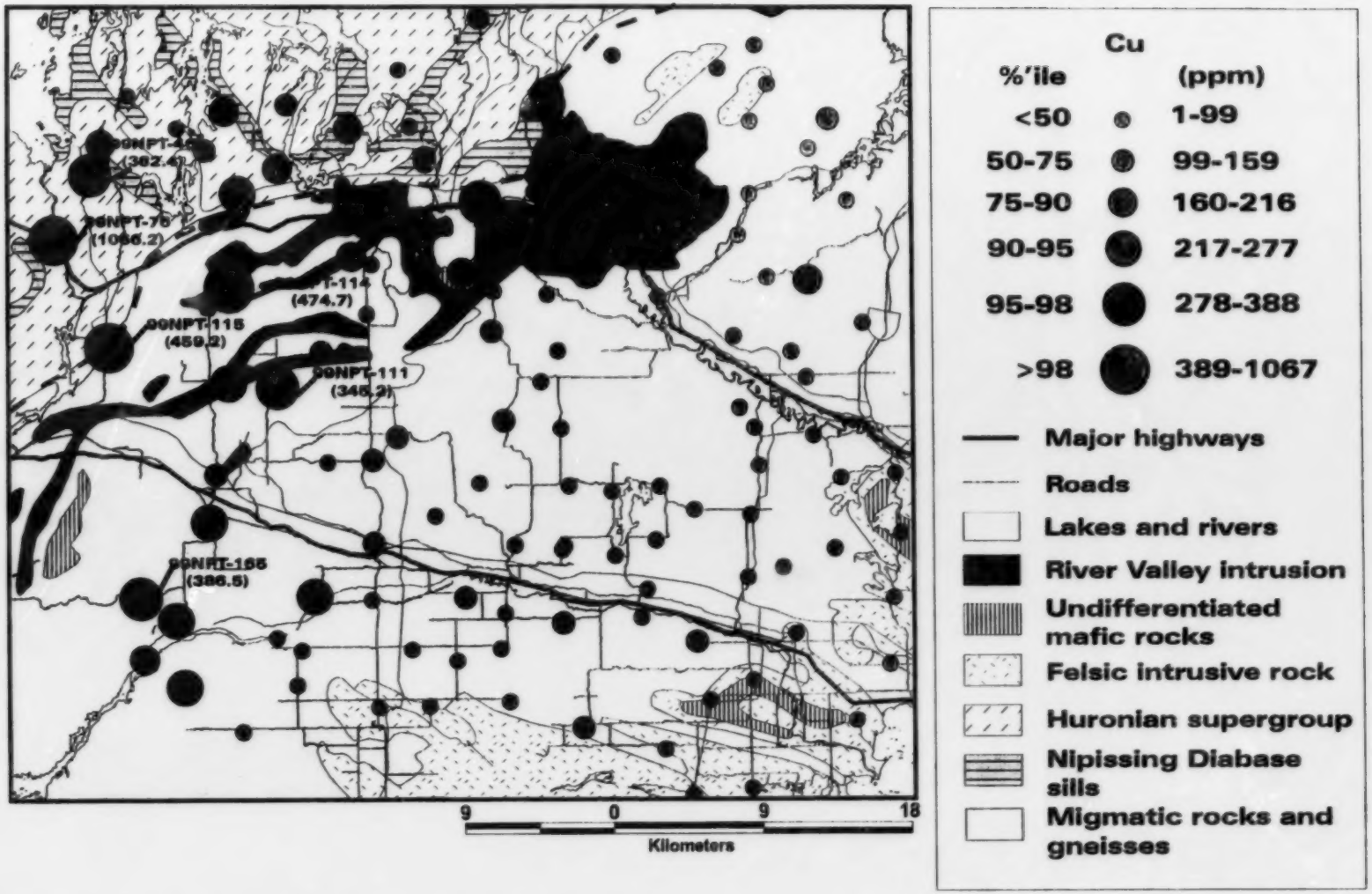


Figure 36: Regional distribution of copper in humus.

RECOMMENDATIONS FOR EXPLORATION

Within the current study area, various samples across the sampling grid show Pt, Pd, Au, Cu and Ni enrichment. Results from C-horizon tills, B-horizon soils and non-ferromagnetic heavy minerals distinctly indicate anomalous bedrock values in the case study sites. The non-ferromagnetic heavy mineral samples yield the highest Pt, Pd, Au, Ni, Cu values, however, cost for analysis is also significantly higher. Thus, C-horizon tills and B-horizon soils can be used as a cost-effective tool for Pt and Pd exploration.

Other elements such as Cr, Co, Fe, Mg, S, As, Sb, Mo, Zn, Pb and Cd have also been analysed. Results can be observed in Tardif (2000, Appendix K).

Indicator Heavy Minerals

INTRODUCTION

For the purpose of this study, heavy indicator minerals (> 3.2 S.G.) are divided into 3 main categories: 1) gold grains; 2) kimberlite indicator minerals (KIMs); and 2) metamorphic massive sulphide indicator minerals (MMSIMs).

LABORATORY METHODS

Overburden Drilling Management (ODM), located in Nepean, Ontario, prepared 171, 7 to 10 kg C-horizon till samples for heavy mineral concentrates (HMC) (Figure 37). Weighed samples were sieved in order to separate the >2 mm fraction (which was subsequently stored). The fine material was passed over a shaking table where the light materials were separated and an initial gold grain count was done. Subsequent panning of the heavy mineral table concentrate for each sample allowed for a more exact grain count. The shape and number of gold grains contained in each sample is recorded in Appendix B, this report. Methylene iodide was used on the <2 mm heavy mineral table concentrate fraction to separate the heavy minerals (>3.2 specific gravity) from the light minerals (<3.2 specific gravity). This heavy fraction underwent a ferromagnetic separation, thus removing the magnetic minerals. Magnetic and non-magnetic fractions were stored separately (Averill 1998). Sample weights of the resulting fractions are recorded in Tardif (2000, Appendix A).

After multiple processes of sieving, washing and magnetic separations (Figure 37), the 0.25 to 2 mm grains were picked and common kimberlite indicator minerals (KIMs) and metamorphic massive sulphide indicator minerals (MMSIMs) were identified. These grains were subsequently stored, mounted in epoxy, then polished and prepared for microprobe analysis.

Gold Grains

Gold grains are commonly silt sized and vary in grain shape depending on the distance of transportation from their source area. Three gold grain appearances are recognized: 1) pristine; 2) modified; and 3) reshaped. According to Bajc (1999), pristine gold grains occur as angular wires, rods and leaves, and contain primary crystal textures such as crystal faces or grain molds.

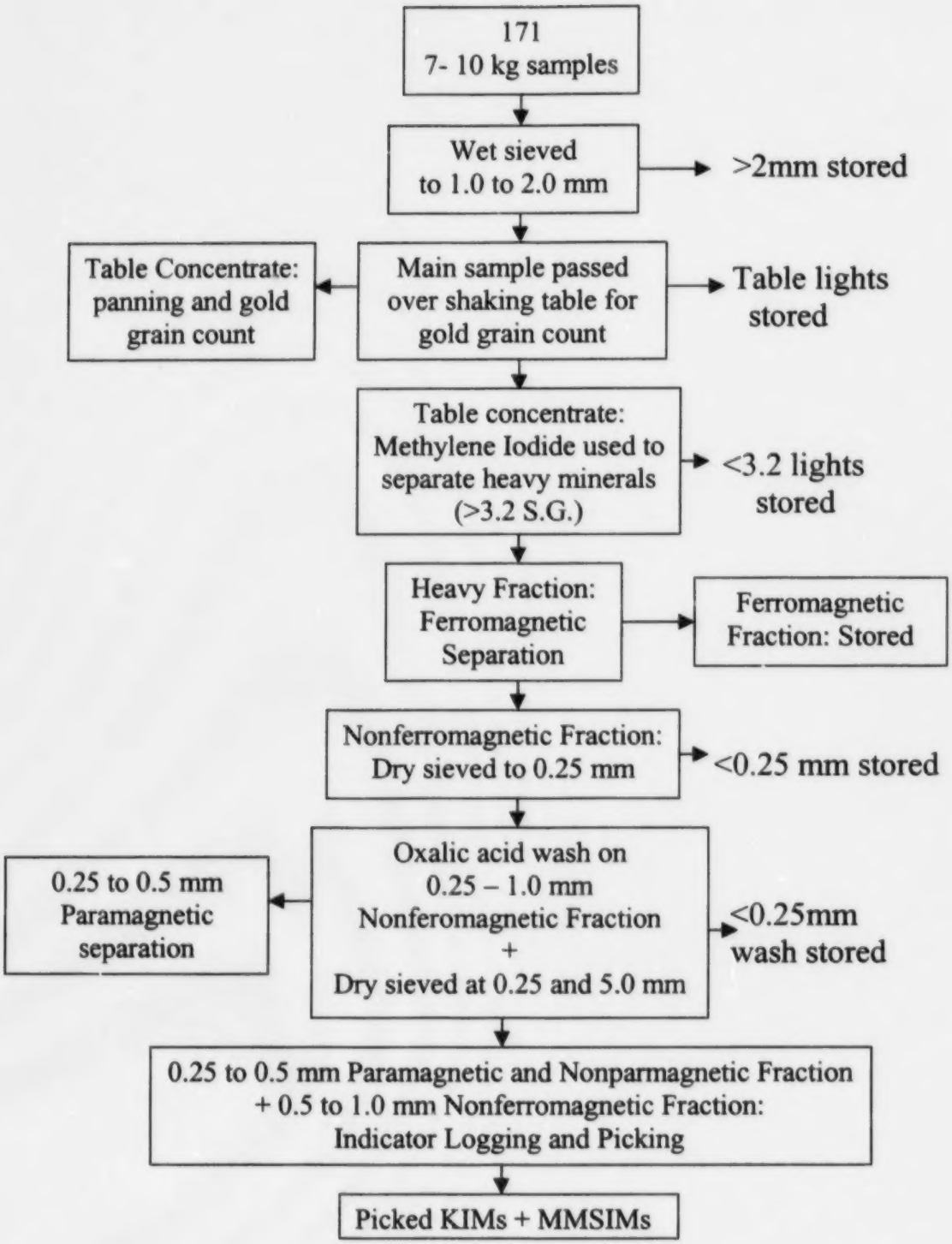


Figure 37: Heavy mineral sample processing flow chart. (Modified from Averill 1998)

Modified grains retain their original shape, however, they have irregular edges and protrusions that are crumpled and curled. Reshaped grains do not retain any of their pristine textures; they are flattened or rounded due to repeated abrasions. Gold grain shapes can be used to determine the transport history of the sample. In general, pristine grains indicate little distance of transport from the source area whereas reshaped grains suggest longer distance of transport. Pristine gold grains in till may also result from *in situ* weathering of transported sulphide grains containing fine, particulate gold. Care should be exercised when interpreting the transportation history of pristine gold grains.

A total of 1561 gold grains were recovered from the 171 samples submitted to Overburden Laboratories (Appendix B, this report). The majority of these grains (1305) were reshaped, however, a significant number of modified (135) and pristine (120) grains were also recovered. The average gold grain recovered was silt sized (<75μm). Background concentrations of gold grains in the area appears to be somewhere in the order of 6 to 10 grains per 8 to 10 kg bulk till sample. The 95th percentile is the parameter used to define the limit of anomalous concentration of gold grains in this study.

Figure 38 shows 3 areas where anomalous gold values are present. Two of these areas correspond with the 2 case study sites. A ratio of the sum of "modified + pristine" grains to the "total" number of grains [(M+P)/T] is illustrated in Appendix B, this report. Where the number of pristine gold grains makes up 50% or more of the total gold grains, local gold mineralization is probable. Regionally, 13 samples contain greater than 50% pristine gold grains (Appendix B, this report). None of these samples contain total gold grains above the 95th percentile.

Within the Dana Lake zone (Figure 39), 6 sample sites (99-NPT-133, 99-NPT-142, 99-NPT-155, 99-NPT-157, 99-NPT-161, 99-NPT-162) contain anomalous total gold grain values. These samples are located both up ice and down ice from the exposed mineralized zones. Nine samples (99-NPT-129, 99-NPT-141, 99-NPT-145, 99-NPT-146, 99-NPT-149, 99-NPT-153, 99-NPT-155, 99-NPT-161, 99-NPT-162) contain anomalous pristine gold grains suggesting a local source. Only one sample contains 50% pristine gold grains (99-NPT-138). However, this sample is not anomalous in total or pristine gold grains. Within bedrock, gold has been recovered within the sulphide-bearing mafic anorthositic rocks. Thus, gold grains in this area are most likely derived from the known mineralized sites as well as within sites currently being exposed by exploration companies up ice from these zones. Within the Azen Creek zone, 2 sites (99-NPT-166 and 99-NPT-169) contain anomalous total gold grain values (Figure 39). One sample site is located south of the exposed mineralized zone where bedrock geochemistry yielded values up to 145 ppb gold (Easton and Hrominchuk 1999). Thus, gold grains within this sample were most likely derived from this area. The other sample sites containing anomalous gold values is located north of the exposed mineralized zone suggesting provenance up ice from this site.

The third anomalous site is located southeast of the Dana Lake and Azen Creek zones. Samples 99-NPT-009, 99-NPT-011 and 99-NPT-012 contain 25, 29 and 21 gold grains respectively, which is considered moderately to highly anomalous.

Platinum Group Minerals (PGMs)

A total of 16 sperrylite grains ($PtAs_2$) and one stibiopalladinite grain (Pd_5Sb_2) were recovered from the Dana Lake and Azen Creek case study areas (Appendix B, this report). These grains have been found in samples collected down ice from the exposed mineralized zones, suggesting a possible local source. At Dana Lake, 7 sample sites (99-NPT-138, 99-NPT-144, 99-NPT-147,

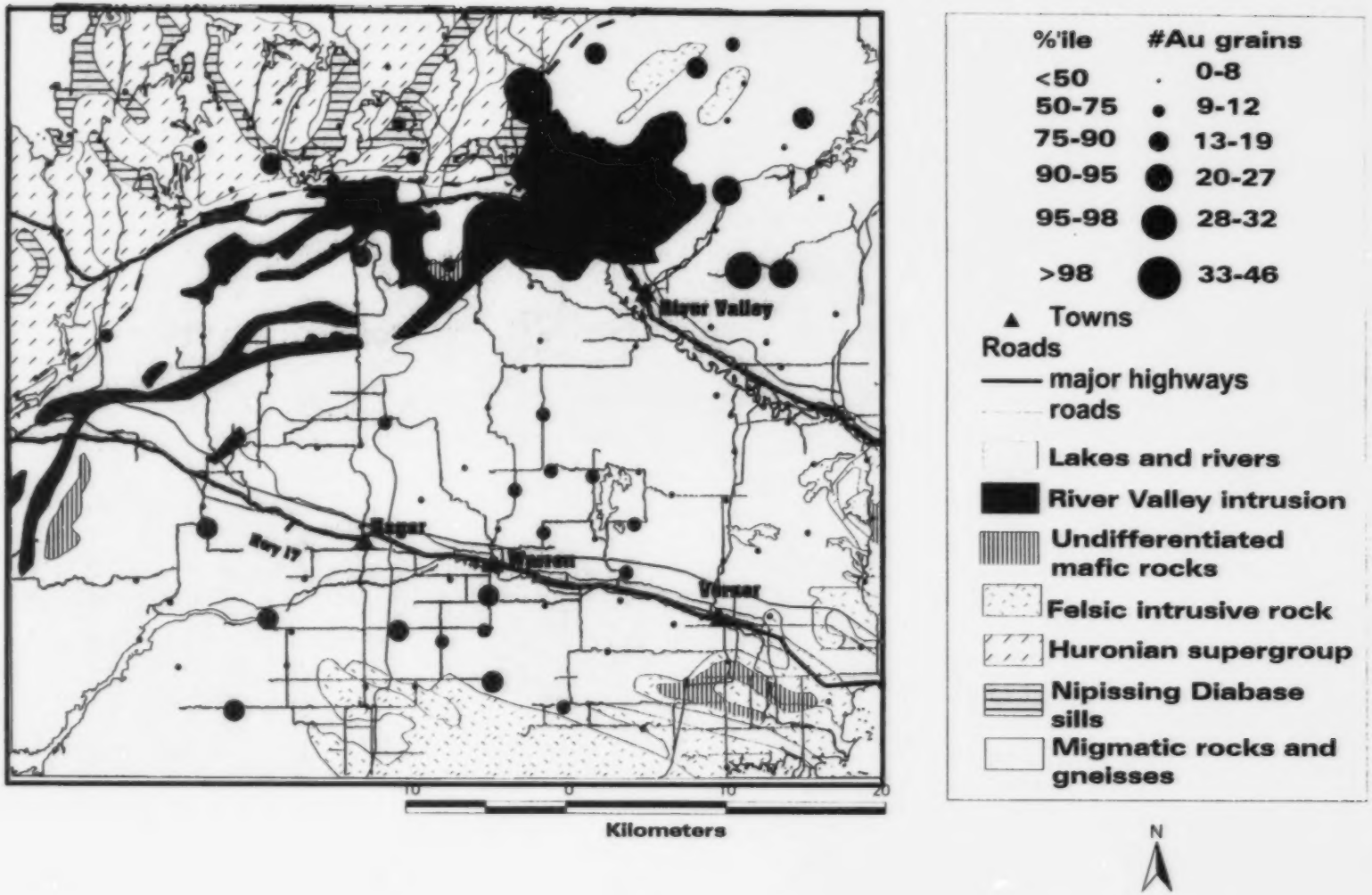


Figure 38: Regional distribution of gold grains recovered from heavy mineral concentrates.

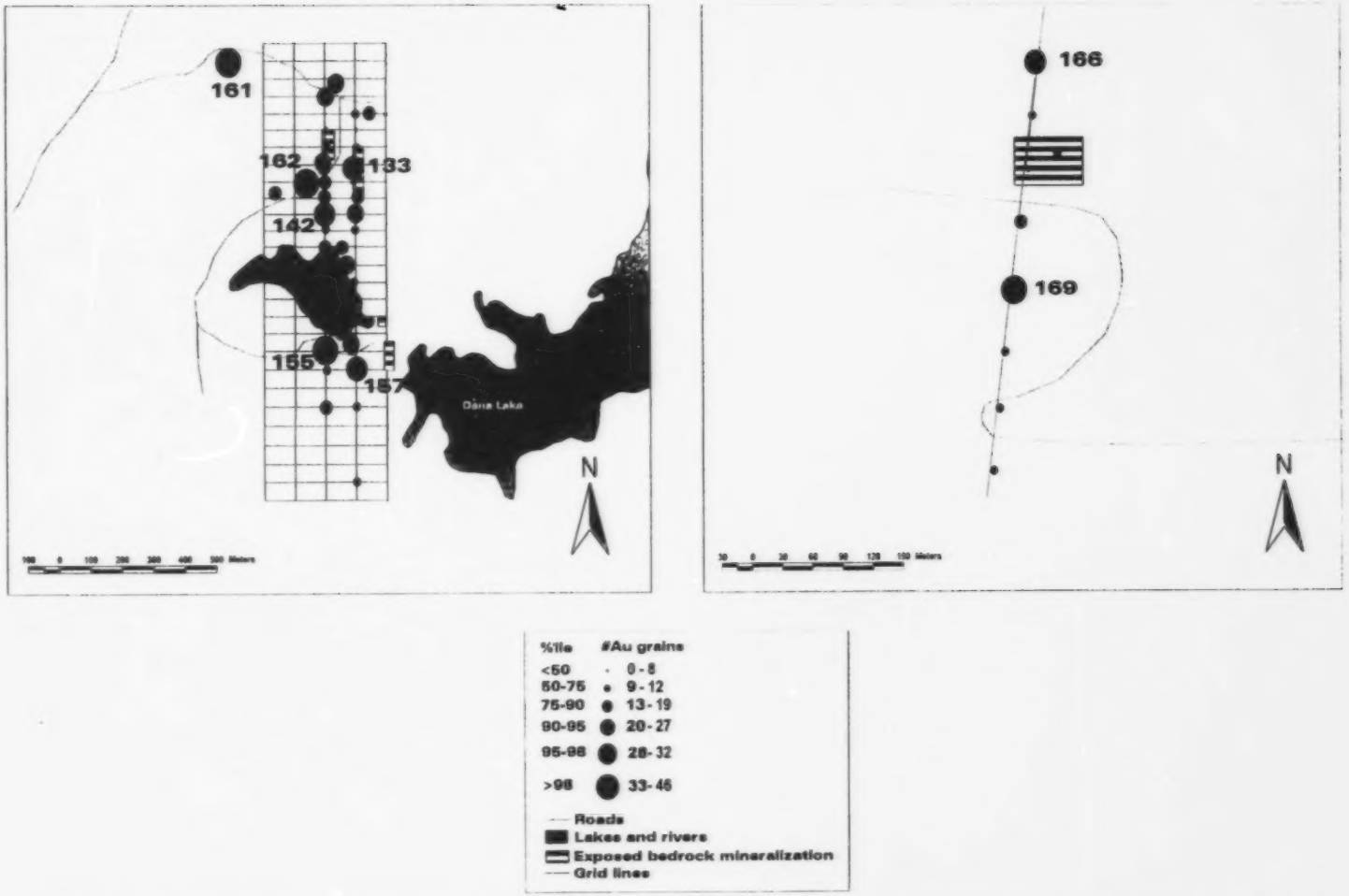


Figure 39: Distribution of gold grains recovered from heavy mineral concentrates within the Dana Lake and Azen Creek case study areas. The suffix 99-NPT- has been dropped from the sample numbers.

99-NPT-148, 99-NPT-155, 99-NPT-159, 99-NPT-160) contain PGM grains and at Azen Creek 2 sample sites (99-NPT-170, 99-NPT-171) contain PGM grains (Figure 40). Samples outside of these case study areas do not contain PGMs, thus their presence is considered anomalous and indicates PGE mineralization up ice from the sample sites.

Heavy Mineral Concentrate

A total of 342 ferromagnetic and nonferromagnetic samples were submitted to the Geoscience Laboratories in Sudbury, Ontario. Where possible, 20 gm to 25 gm of the non-magnetic fraction was pulverized to 200 μm in preparation for analysis. Considering the small weights of the magnetic samples, the total weight was pulverized to 200 μm (Tardif 2000, Appendix A).

The non-magnetic heavy mineral fractions were submitted to the Geoscience Laboratories for inductively coupled plasma-mass spectrometry (ICP-MS) with aqua-regia digestion and lead fire assay, analyzing for Au, Pt and Pd. The magnetic fractions, due to their small sample weights, were only submitted for ICP-MS analysis.

KIMBERLITE INDICATOR MINERALS (KIMs)

Thirty-two samples were randomly picked from the study area and submitted for kimberlite indicator mineral analysis. KIMs are a suite of heavy minerals related to kimberlite or lamproite, potential host rocks to diamonds. Common indicators found in this study include peridotitic Cr-pyrope garnets, megacrystic Cr-poor pyrope garnets, crustal eclogitic pyrope-almandine garnets, Cr-diopside, Mg-rich ilmenites and chromites. Kimberlite indicator grains picked from the 32 samples are recorded in Appendix C, this report.

Garnet

Garnet minerals originate from many types of peridotites but the most important are harzburgite and lherzolite (Stephenson et al. 1999) because of their association with diamonds. Most garnets from harzburgite peridotites ("G10" garnets) occur as inclusions in diamonds and are characterized by Ca depletion and Cr enrichment (Gurney 1984). This close association of harzburgitic "G10" garnets to diamonds suggests that they are more strongly associated with diamonds than "G9" garnets of lherzolitic origin (Dawson and Stephens 1975).

Other important KIMs are eclogitic garnets. These are Cr-poor and range from pyrope to almandine-pyrope in composition (Stephenson et al. 1999). Diamondiferous eclogitic garnets typically have Na_2O concentrations greater than 0.07% (Fipke et al. 1995) in conjunction with generally low TiO_2 values. Eclogitic garnets with low Na concentrations are crustal in origin and may also be useful indicators if found with other KIMs (Stephenson et al. 1999). Garnets containing higher TiO_2 values (>0.4 wt%) in conjunction with low Na values and low levels of Cr (<2 wt%) are of the megacrystic suite and are not directly related to diamonds. However, if found with other KIMs, they may be useful indicators.

Microprobe analysis of 60 grains submitted to the Geoscience Laboratories revealed 40 "G9" Cr-pyrope garnets and 2 "G10" Cr-pyrope garnets (from samples 99-NPT-091 and 99-NPT-105) of peridotitic origin (Figure 41). One grain (99-NPT-031GP2) is slighlty within the "G10 field" and could be condsidered a "G10" garnet. However, the boundaries contain marginal errors, thus care should be taken considering this grain. Of the remaining 18 grains, none classify

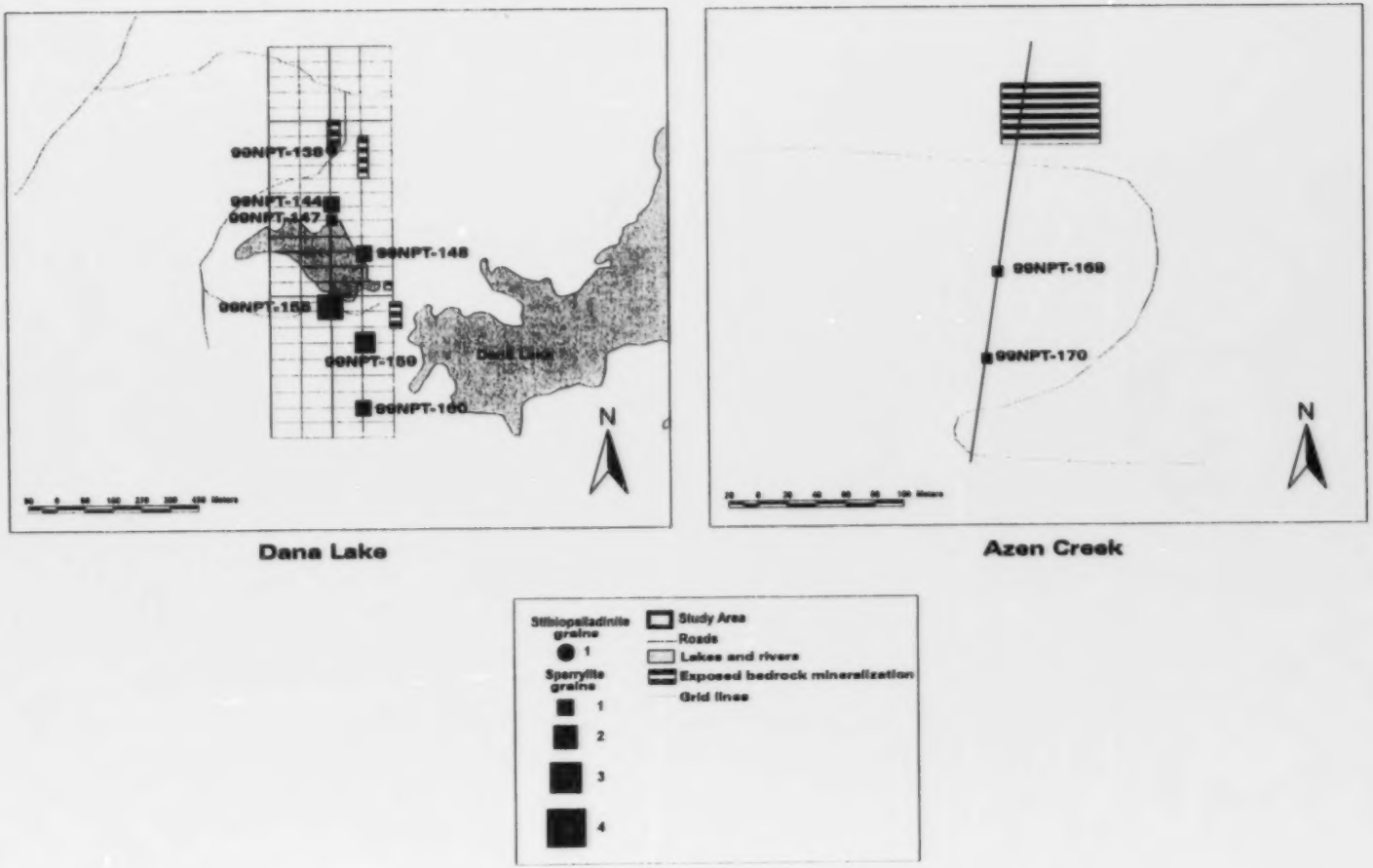
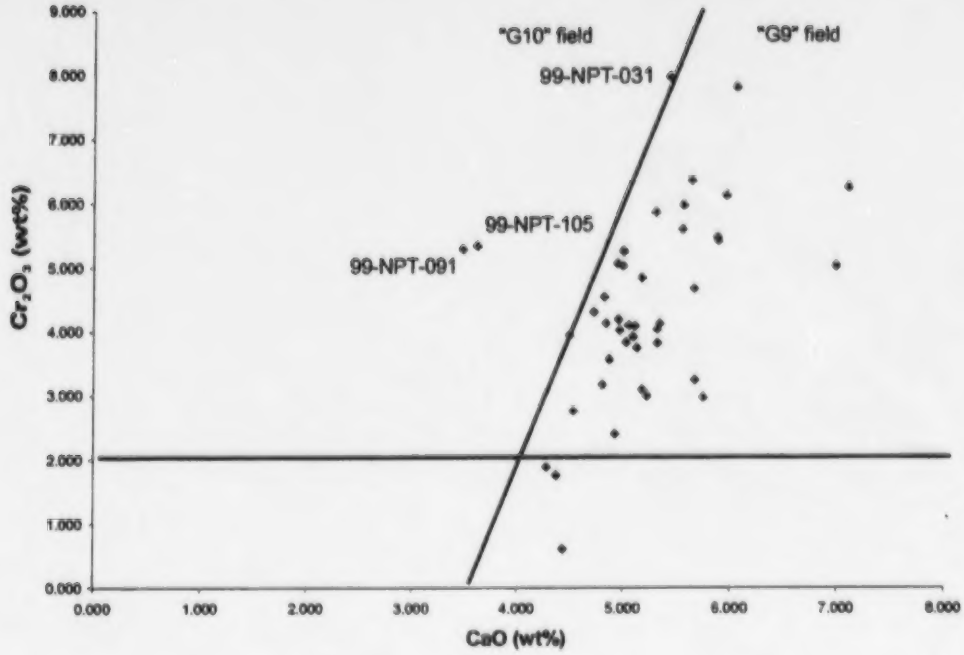
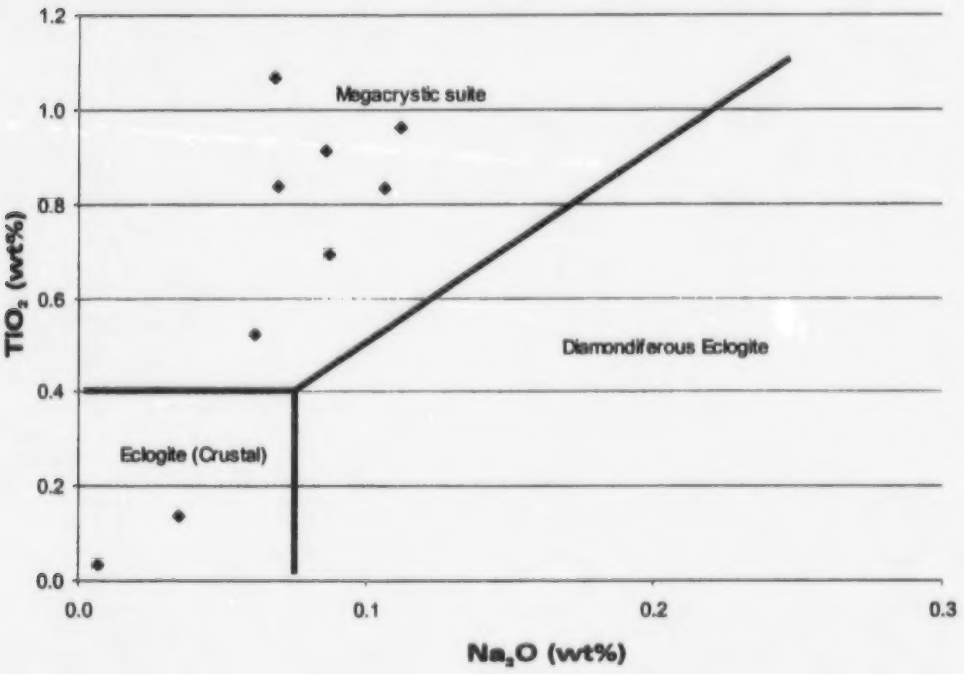


Figure 40: Distribution of Platinum Group Minerals: Sperrylite and Stibiopalladinite at Dana Lake and Azen Creek case study areas.



A



B

Figure 41: A- "G10" and "G9" Cr-pyrope garnet Cr_2O_3-CaO plot (after Dawson and Stephens 1975). B- Eclogitic Garnet TiO_2-Na_2O plot (after Fipke et al. 1995).

as diamondiferous eclogites, 2 are crustal eclogites (99-NPT-095-GP-1 and 99-NPT-080-GP-3) and 7 fall in the megacrystic suite (Figure 41). Other garnets identified include almandine, Mn-almandine, spessartine and andradite. These are not likely associated with kimberlite and are of little interest to kimberlite exploration. Geochemistry for all garnet grains is listed in Tardif (2000, Appendix F).

The distribution diagram based on the Cr-pyrope garnet data shows that the eastern part of the study area has anomalous or elevated concentrations of "G9" and "G10" garnets (Figure 42) (99-NPT-003, 99-NPT-024, 99-NPT-031, 99-NPT-034, 99-NPT-036, 99-NPT-080, 99-NPT-082, 99-NPT-088, 99-NPT-091, 99-NPT-092, 99-NPT-095, 99-NPT-105, 99-NPT-128, 99-NPT-129, 99-NPT-145, 99-NPT-156).

Chromite

A chromite grain plotting in the "diamond inclusion field" of a wt % Cr_2O_3 vs MgO diagram is as significant as finding a "G10" garnet. These chromites are characterized by a Cr_2O_3 content generally greater than 61 wt% (Gurney 1984) and an MgO content greater than 10 wt% (Fipke et al. 1995). To determine whether chromites originate from lamproites and kimberlites, a wt % Cr_2O_3-TiO_2 plot (Fipke et al. 1995) can be used. Chromites plotting in the overlap field and in the field unique to kimberlites and lamproites of the wt% Cr_2O_3-TiO_2 plot are included in the KIM data set.

Thirty-nine chromite grains were submitted for microprobe analysis. Twelve of these grains were identified as ilmenites. None of the remaining 27 grains plotted in the diamond inclusion field of the wt% Cr_2O_3 vs MgO diagram (Figure 43) and only 3 grains (99-NPT-078, 99-NPT-070, 99-NPT-076) plotted in the field unique to kimberlite and lamproite on a wt% TiO_2 vs. wt% Cr_2O_3 diagram (Figure 43). Caution must be taken when dealing with these 3 samples because they plot near the border between the field unique to lamproites and kimberlites and the overlap field. The remaining 21 grains plotted in the overlap field. These have all been included in the KIM™ data set (Tardif 2000, Appendix G).

The distribution diagram based on chromite grain data shows 2 distinct areas of chromite concentration. One area is located in the northeast corner of the study area (99-NPT-003, 99-NPT-031, 99-NPT-034, 99-NPT-036, 99-NPT-128, 99-NPT-145, 99-NPT-156) and the second is in the western part of the area, at the boundary between Scadding and Street townships (99-NPT-076, 99-NPT-078) (Figure 44).

Mg-Ilmenite

Ilmenites found within kimberlites contain MgO values between 4 and 15 wt%, and Cr_2O_3 values greater than 2 wt% (McCallum and Vos 1993). These ilmenites are considered useful kimberlite indicator minerals (Morris and Kaszycki 1997) when found in conjunction with other KIMs.

Thirteen Mg-ilmenites underwent microprobe analysis (Tardif 2000, Appendix H). These grains are plotted on Gurney and Moore's (1991) Mg-ilmenite parabolic plot in order to determine whether they originated from a reducing environment (favorable for diamond preservation within the magma) or from an oxidizing environment (conductive to diamond resorption into the magma)(Figure 45). Four grains plotted in the reducing environment field and were included in the KIM data set (Table 1). Only 2 of these 4 grains contain Cr values greater than 2 wt% (both grains in sample 99-NPT-003).

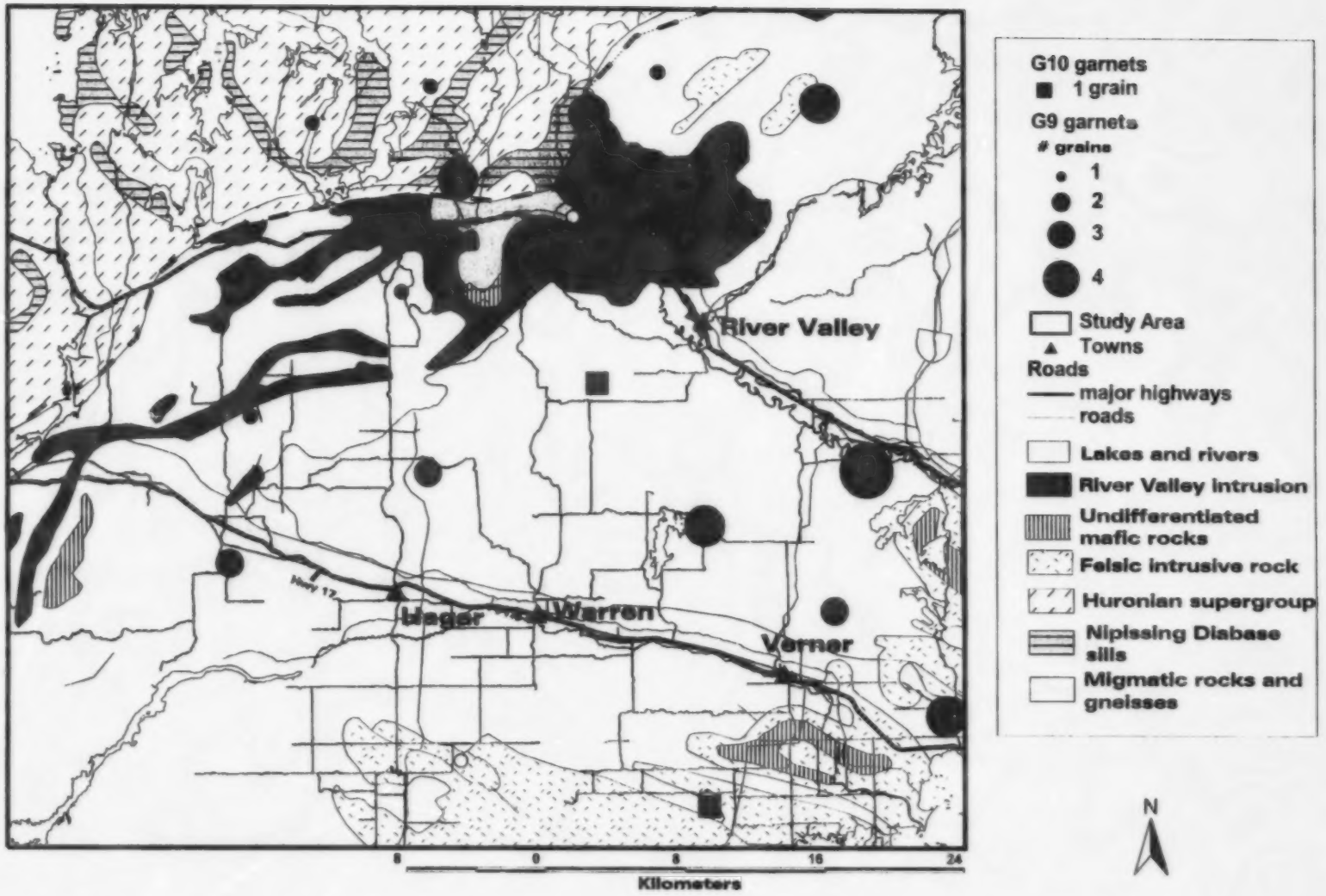


Figure 42: Regional distribution of Cr-pyrope garnet (G9+G10) grains.

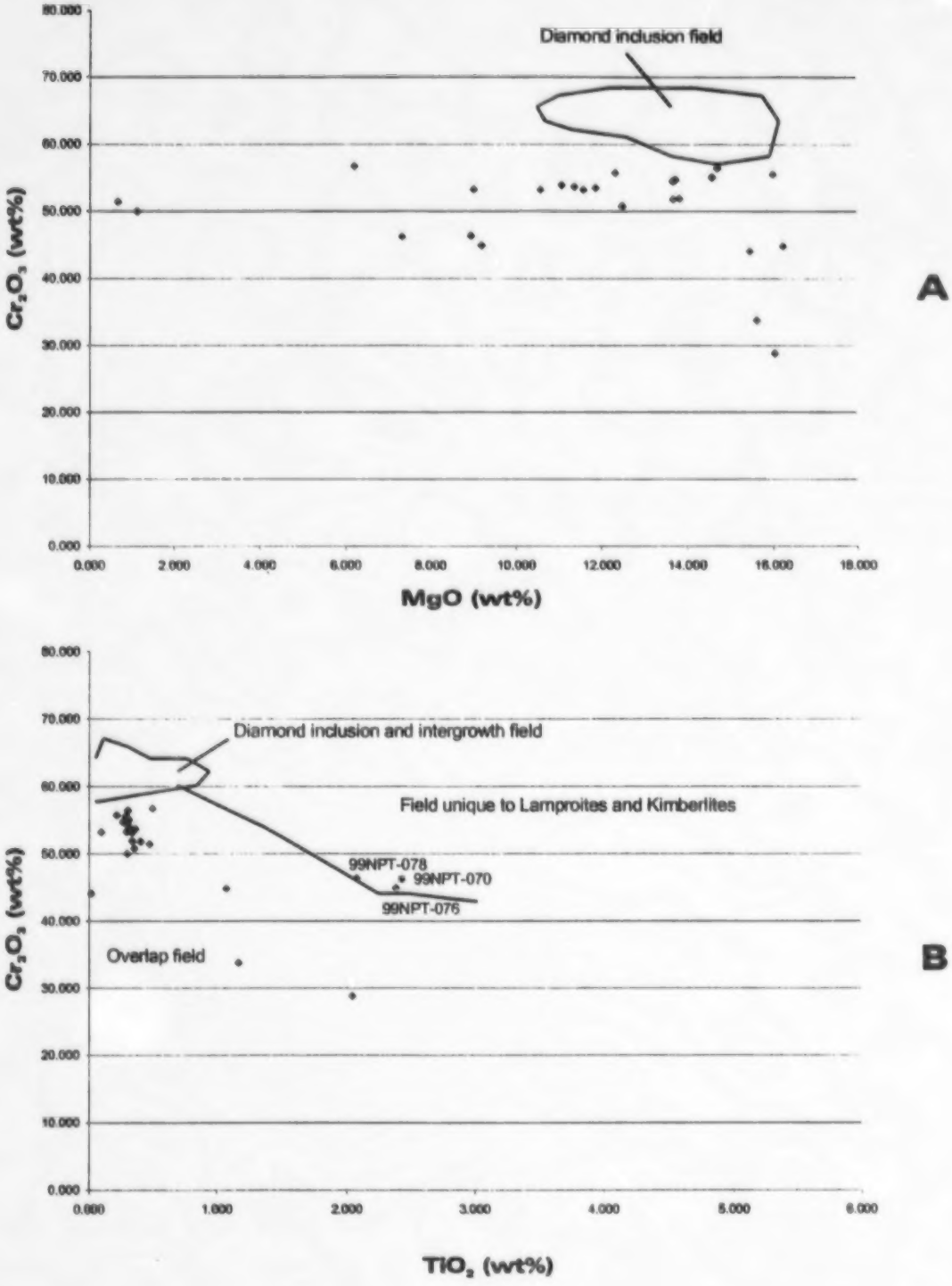


Figure 43: A- Chromite Cr_2O_3-MgO plot. B- Chromite Cr_2O_3-TiO_2 plot. (After Fipke et al. 1995)

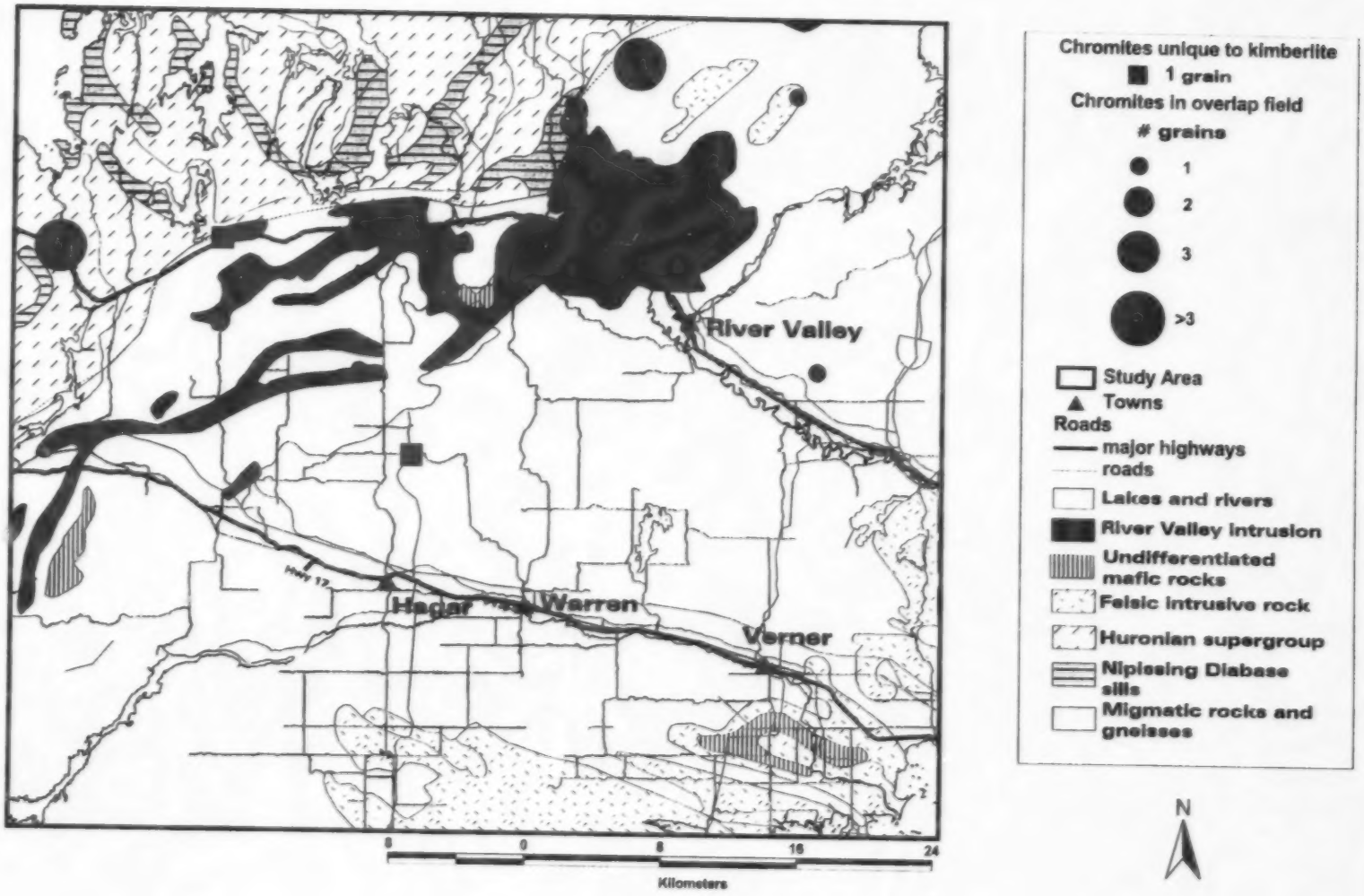


Figure 44: Regional distribution of chromite grains.

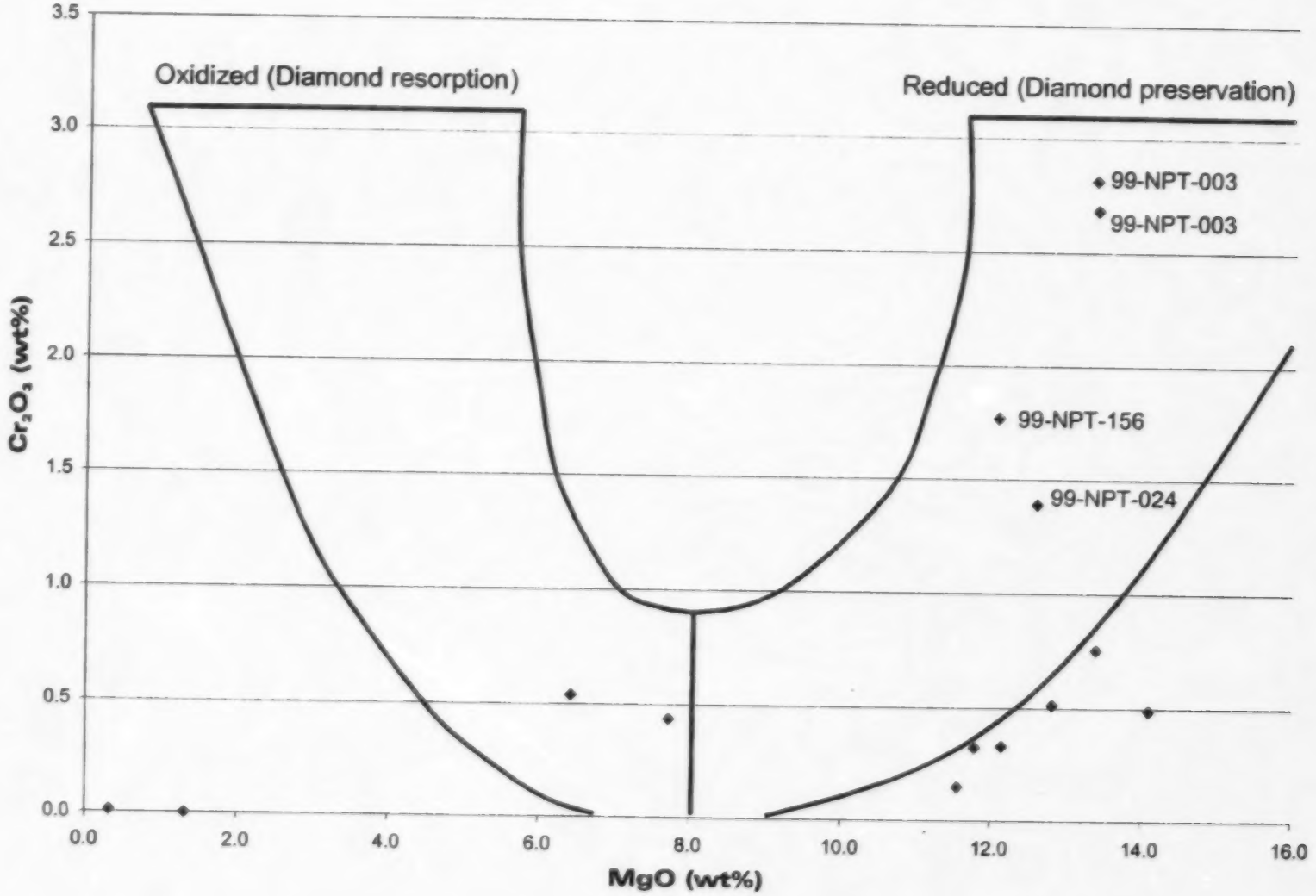


Figure 45: Mg-ilmenite Cr_2O_3-MgO plot (after Gurney and Moore 1991).

Sample	UTM East	UTM North	Garnets	Chromite	Mg-ilmenite	Cr-diopside	total KIM grains
99NPT-003	568673	5173307	4	1	2	0	7
99NPT-018	570021	5157140	0	1	0	1	2
99NPT-024	575902	5138301	3	0	1	1	5
99NPT-031	559147	5167444	5	2	0	1	8
99NPT-034	554553	5166755	1	1	0	0	2
99NPT-036	559347	5175044	1	4	0	0	5
99NPT-045	544657	5162376	1	0	0	1	2
99NPT-053	539525	5172000	2	0	0	0	2
99NPT-058	548044	5135729	1	0	0	5	6
99NPT-069	548436	5147270	0	0	0	2	2
99NPT-070	546161	5152020	2	1	0	1	4
99NPT-072	552075	5160732	0	0	0	2	2
99NPT-076	525435	5163829	0	9	0	1	10
99NPT-078	534945	5164476	0	1	0	0	1
99NPT-080	547923	5168782	3	0	0	0	3
99NPT-082	546342	5174145	1	0	0	0	1
99NPT-083	567644	5137345	0	0	0	1	1
99NPT-088	571343	5152165	4	0	0	0	4
99NPT-091	555921	5157170	2	0	0	0	2
99NPT-092	562044	5149057	3	0	0	9	12
99NPT-095	569468	5144211	2	0	0	1	3
99NPT-105	562295	5133137	3	0	0	4	7
99NPT-106	556158	5140813	0	0	0	8	8
99NPT-112	535994	5155214	1	0	0	1	2
99-NPT-114	536067	5160964	0	0	0	0	0
99NPT-115	528774	5157363	0	0	0	2	2
99NPT-119	534790	5146856	2	0	0	0	2
99NPT-126	533262	5136899	0	0	0	4	4
99NPT-128	555425	5172579	4	1	0	1	6
99NPT-129	555463	5172541	1	0	0	0	1
99NPT-145	555354	5172072	3	1	0	1	5
99NPT-156	555488	5171509	1	2	1	0	4
		Total	50	24	4	47	125

Table 1: Kimberlite indicator mineral grains collected from 32 randomly selected samples. Samples containing numbers of grains above the 95th percentile are anomalous.

The distribution diagram for Mg-ilmenites shows only 1 sample area containing anomalous values of Mg-ilmenite grains, located in the northeast section of the study area at sample site 99-NPT-003 (Figure 46).

Cr-Diopside

Cr-diopsides can be found in both megacrystic and groundmass phases within kimberlites (Morris et al. 1999) and in basic and ultramafic rocks. For this reason Cr-diopside on its own is not a good indicator mineral. However, when found with other indicator minerals, Cr-diopside is a useful KIM. Morris et al. (2000) have developed a new method of determining Cr-diopsides as indicator minerals using a Cr_2O_3, Al_2O_3 and Na_2O molecular wt % ternary plot. This plot has been tested on kimberlites and other rock types (Morris et al. 2000) and seems to isolate Cr-diopsides associated with kimberlites.

In this study, 106 Cr-diopside grains were sent to Geoscience Laboratories for microprobe analysis. Forty-seven of these grains plotted in the "kimberlite field" of Morris et al.'s (2000) ternary plot (Figure 47) and have been added to the KIM data set (Tardif 2000, Appendix I). The distribution diagram for Cr-diopsides (Figure 48) indicates an area containing an anomalous number of Cr-diopsides. This area is located in the southern to southeastern corner of the study area (99-NPT-058, 99-NPT-092, 99-NPT-105, 99-NPT-106).

Recommendations for Kimberlite Exploration

The average sample from the River Valley area contains between 1 to 6 KIM grains indicating that sources likely exist up ice. The exploration targets within the study area (Figure 49) are based on sample sites containing significant KIMs such as "G10" garnets, Mg-ilmenites and chromites unique to lamproites and kimberlites.

Proximity to Source

Given the glacial history of the area, pebble lithologies from each sample can be used to estimate proximity to source. A sample with a local mix of pebbles may suggest close proximity to source as opposed to samples containing exotic pebbles. All significant KIM samples in this study contain large amounts of pebbles that correspond with rock types observed within the study area (Tardif 2000, Appendix E). For example, the 2 sites where the "G10" Cr-pyrope garnets were recovered (99-NPT-091 and 99-NPT-105) both have relatively low percentages of exotic pebbles suggesting a close proximity to source.

Samples near structural uncomformities such as faults or dykes, and/or samples containing anomalous values of KIMs that are located near circular-ellipsoid magnetic signatures also suggest proximity to source (Morris and Kazycki 1997). Approximately 160 km east of the study area is the Ottawa-Bonnechere Graben. This fault zone is associated with a magnetic anomaly and contains lamproites dykes (Sage 1991).

Close proximity to source may also be suggested by the presence of Cr-diopside and olivine (99-NPT-003, 99-NPT-095), since these minerals break down easily in surface environments (Stephenson et al. 1999).

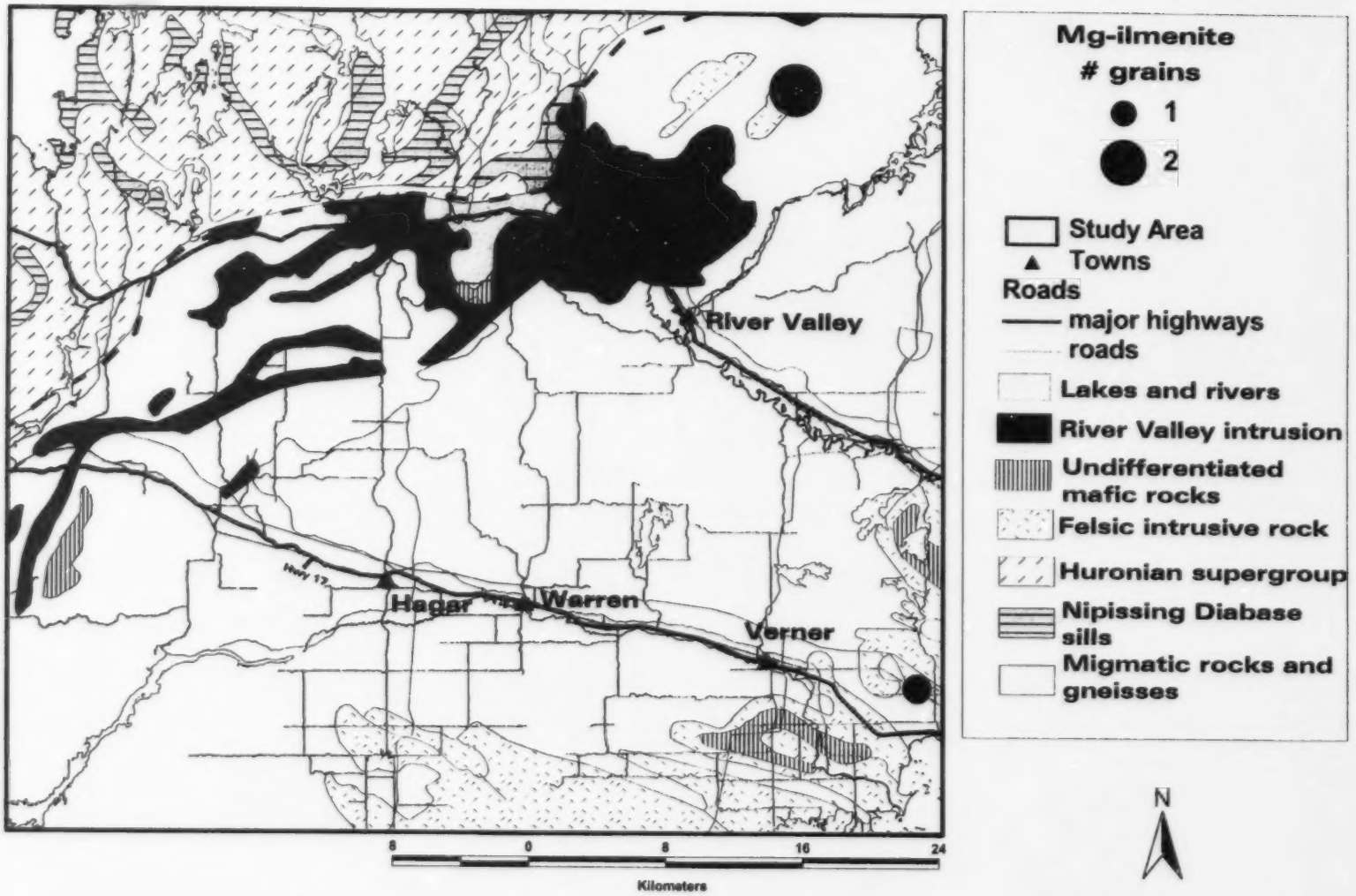


Figure 46: Regional distribution of Mg-ilmenite grains.

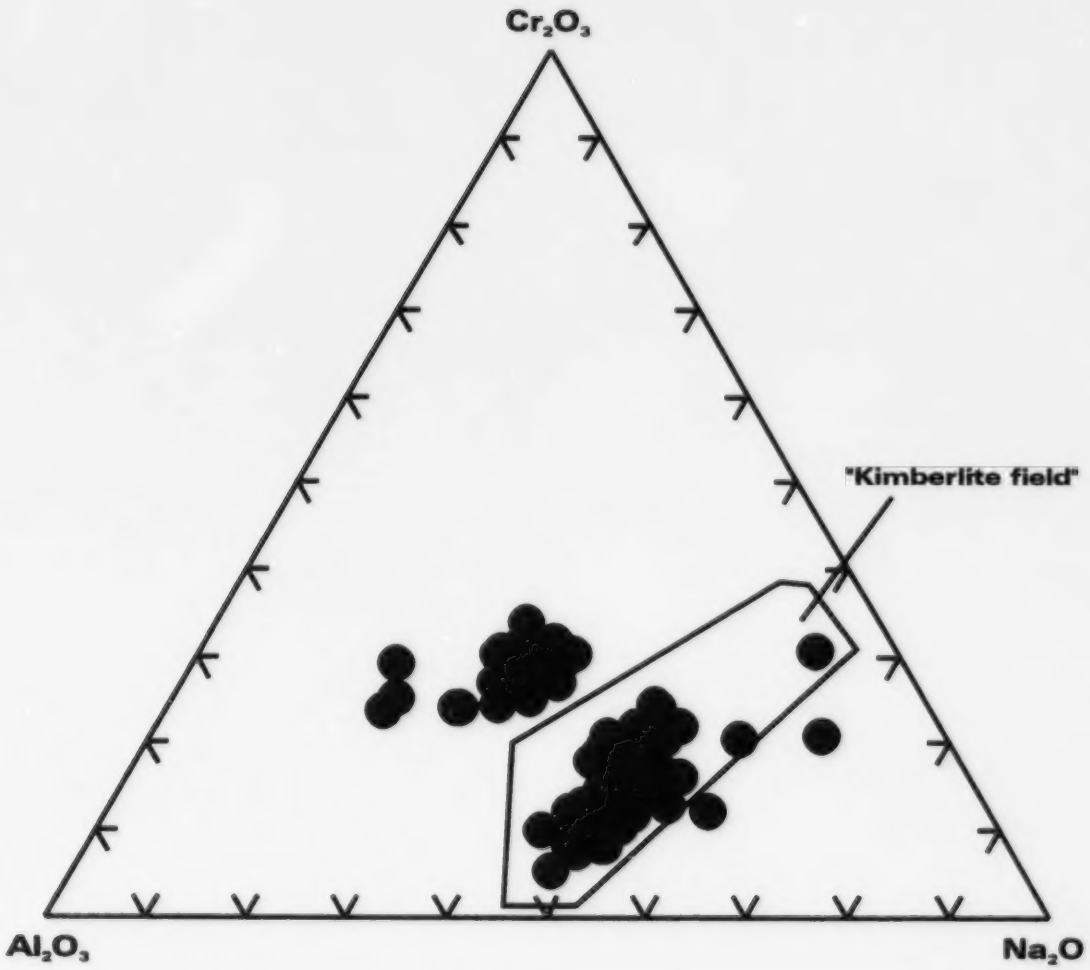


Figure 47: Cr_2O_3, Al_2O_3 and Na_2O ternary plot for pyroxenes. (After Morris et al. 2000)

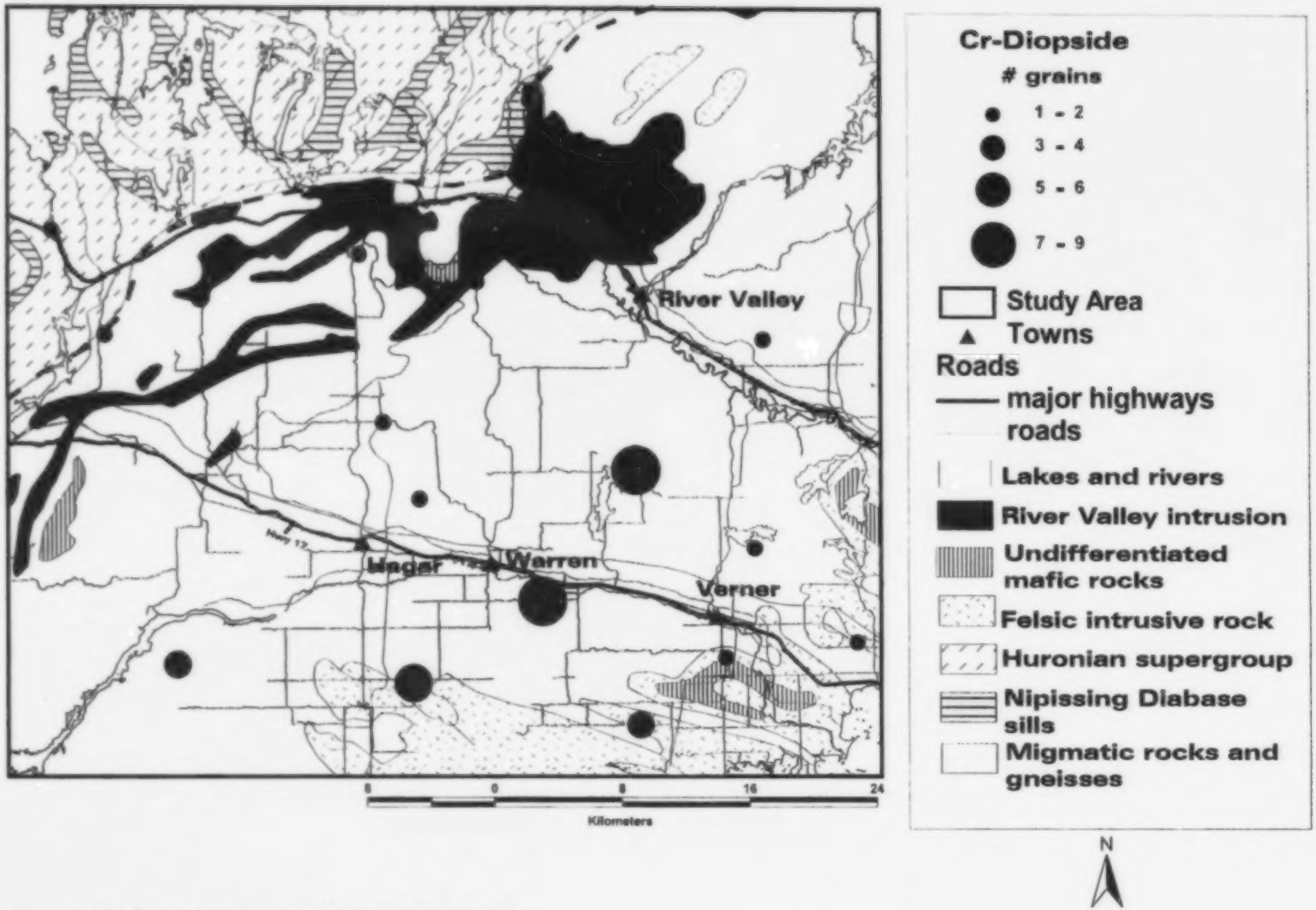


Figure 48: Regional distribution of Cr-diopside.

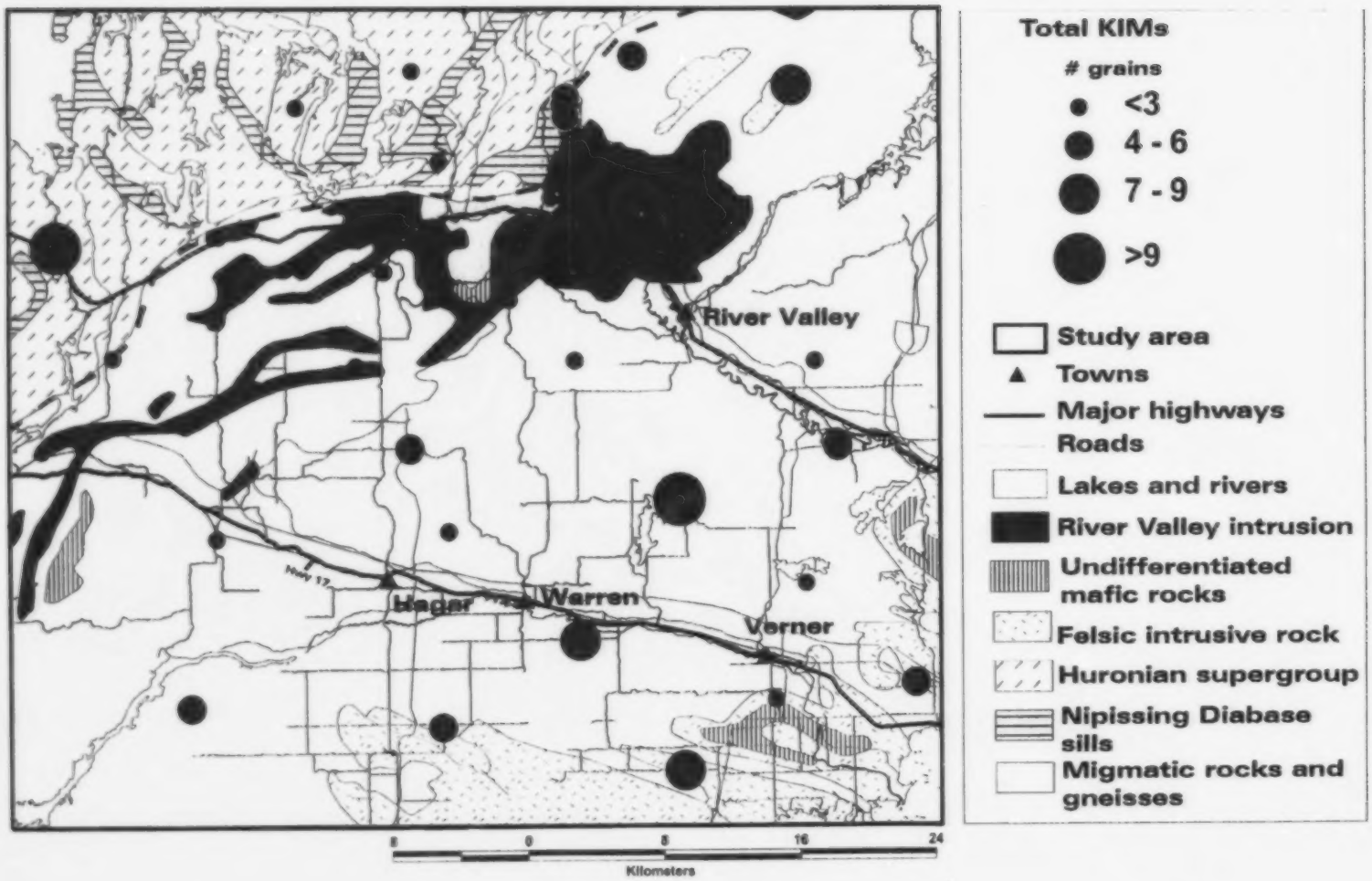


Figure 49: Regional distribution of all kimberlite indicator minerals.

METAMORPHIC MASSIVE SULPHIDE INDICATOR MINERALS (MMSIMs)

MMSIMs are stable heavy minerals that occur in large alteration zones associated with 3 main types of deposits: 1) volcanogenic massive sulphides (VMS) in high grade metamorphic terrains; 2) skarn and greisen deposits; and 3) magmatic Ni-Cu sulphides (Averill 1999). MMSIMs found in this study include chalcopyrite, pyrite, olivine (fayalite), spessartine, chromite, red rutile, Cr-kyanite, bronzite, Cr-diopside and gahnite. Sperrylite ($PtAs_2$) and stibiopalladinite (Pd_5Sb_2) are also relatively stable minerals and can be used as MMSIMs (Averill 1999).

Grains picked from the 32 samples submitted for MMSIM analysis are recorded in Appendix D, this report. Grains submitted for microprobing include Cr-diopside, chromite, gahnite, Cr-kyanite and olivine. Summary statistics for MMSIM data are given in Table 2 and the microprobe analysis data for MMSIMs including Cr-diopside, chromite and olivine is presented in Tardif (2000, Appendices G and I).

Cr-Diopside

Cr-diopside grains are very useful Ni-Cu indicators due to their extreme abundance in Ni-bearing pyroxenites and peridotites (Averill 1999).

A total of 106 Cr-diopside grains were plotted on Morris et al.'s (1999) ternary plot (Figure 47). Samples that plotted in the KIM field were identified as kimberlite indicator minerals and samples plotting out of this field were identified as other rock types. Pyroxenes as MMSIMs generally contain Cr_2O_3 values less than 1.3 wt%. Thus, samples that did not plot in the KIM field of the Cr_2O_3, Al_2O_3 and Na_2O ternary diagram and that contained Cr_2O_3 values less than 1.3 wt% were included in the MMSIM data set.

A total of 53 Cr-diopside grains were identified as MMSIMs in this study (Table 2). Of these, only one sample (99-NPT-034) contained a notable number of grains.

Chromite

Chromites that do not plot in the kimberlitic field of the Cr_2O_3-TiO_2 diagram (Fipke et al. 1995) are included in the MMSIM data set. Chromite is an indicator for alteration zones in metamorphosed VMS deposits and in Ni-Cu massive sulphide deposits (Averill 1999).

A total of 21 chromite grains representing MMSIMs were recovered from the study area. Only 1 site shows yielded a significant number of grains of this mineral, 99-NPT-076.

Gahnite

Gahnite is an indicator of polymetallic deposits in high grade metamorphic terrains (Parr 1992). It has been successfully evaluated as an indicator mineral in glacial dispersal plumes from the Montauban polymetallic deposit in Quebec (Lalonde et al. 1994). However, gahnite can also be an indicator of pegmatite. The MgO content of the mineral distinguishes the 2; MgO values greater than 2 wt % generally indicates gahnite from polymetallic deposits and MgO values less than 2 wt % generally indicates gahnite from rare-element pegmatites (Stephenson et al. 1999).

Sample #	Metamorphic massive sulphide indicator minerals (MMSIMs)										
	Fayalite	gahnite	Cr-kyanite	Red Rutile	Bronzite	Spessartine	Chalcopyrite	Pyrite	Chromite	Cr-diopside	Total MMSIMs
003	5	0	0	2	3	0	0	0	1	0	11
018	0	0	0	1	0	3	0	0	1	1	6
024	0	0	0	2	0	0	6	0	0	1	9
031	0	0	0	3	0	0	6	7	2	2	20
034	0	0	0	1	0	4	4	0	1	10	20
036	0	0	0	0	0	0	0	0	4	1	5
045	0	0	0	28 (200)	0	0	0	0	0	1	29
053	0	0	0	0	0	0	0	0	0	5	5
058	0	0	0	3	0	0	0	0	0	1	4
069	0	0	0	6	0	0	0	0	0	1	7
070	0	0	0	1	0	0	0	0	0	2	3
072	0	0	0	14	0	5	0	0	0	1	20
076	0	0	0	2	0	0	0	0	8	1	11
078	0	0	0	1	0	0	0	0	0	2	3
080	0	0	0	3	0	0	0	0	0	4	7
082	0	0	0	0	0	0	0	0	0	4	4
083	0	0	0	1	0	0	0	0	0	0	1
088	0	0	0	2	0	0	0	0	0	0	2
091	0	0	0	4	0	0	0	0	0	0	4
092	0	0	0	2	0	0	0	0	0	2	4
095	0	0	0	4	0	0	0	0	0	0	4
105	0	0	0	1	0	0	0	0	0	0	1
106	0	0	0	4	0	0	0	0	0	1	5
112	0	0	1	7	0	0	0	0	0	1	9
114	0	0	0	8	0	0	0	0	0	0	8
115	0	0	0	4	0	0	0	0	0	0	4
119	0	1	0	9	0	0	0	0	0	0	10
126	0	0	0	9	0	0	0	0	0	1	10
128	0	0	0	1	0	0	0	0	1	6	8
129	0	0	0	0	0	0	0	0	0	3	3
145	0	0	0	0	0	0	0	0	1	0	1
156	0	0	0	0	0	0	0	0	2	2	4
Total	5	1	1	123	3	12	16	7	21	53	242

Table 2: Metamorphic massive sulphide indicator mineral grains collected from 31 randomly selected samples. Numbers in brackets are an estimated number of grains, based on observations during heavy mineral picking.

Only one gahnite grain was recovered from the study area (99-NPT-119). This grain contains an MgO content <2 wt% and thus is potentially derived from rare-element pegmatite.

Red Rutile

Red rutile containing Cr is a good indicator for metamorphosed VMS deposits (Averill 1999). Within a Ni-Cu massive sulphide deposit, the removal of large volumes of Fe from the silicate phase of the magma to form massive pyrrhotite and Ni-Cu sulphides tends to increase the Mg content of olivine and pyroxene and may transfer Cr from chromite to Fe-free minerals such as rutile (Averill 1999).

In this study, a total of 123 rutile grains were picked from 32 samples submitted to ODM laboratories. The only rutile anomaly is in sample 99-NPT-053, which contains approximately 200 grains. Other samples (99-NPT-072, 99-NPT-003, 99-NPT-112) contain average to high amounts of rutile. The association of these samples with other MMSIMs generates interest to these sample sites.

Other MMSIMs

The rest of the MMSIMs (fayalite, Cr-kyanite, bronzite, spessartine, chalcopyrite and pyrite) unless associated with other indicator minerals are not abundant enough to be significant in this study (Table 2).

Recommendations for massive sulphide exploration

Considering the total number of MMSIMs present at each site, few exploration targets of high quality can be recommended. Sites 99-NPT-003, 99-NPT-031, 99-NPT-034, 99-NPT-045 and 99-NPT-072 are the only areas containing anomalous MMSIMs (above the 95th percentile). These sample sites are located in the northern part of the study area, above bedrock of the River Valley mafic intrusion (Figure 50). Based on pebble lithology data and the presence of unweathered olivine (99-NPT-003) and Cr-diopside (see Table 2) sources for the MMSIM grains appear to be derived from proximal sources.

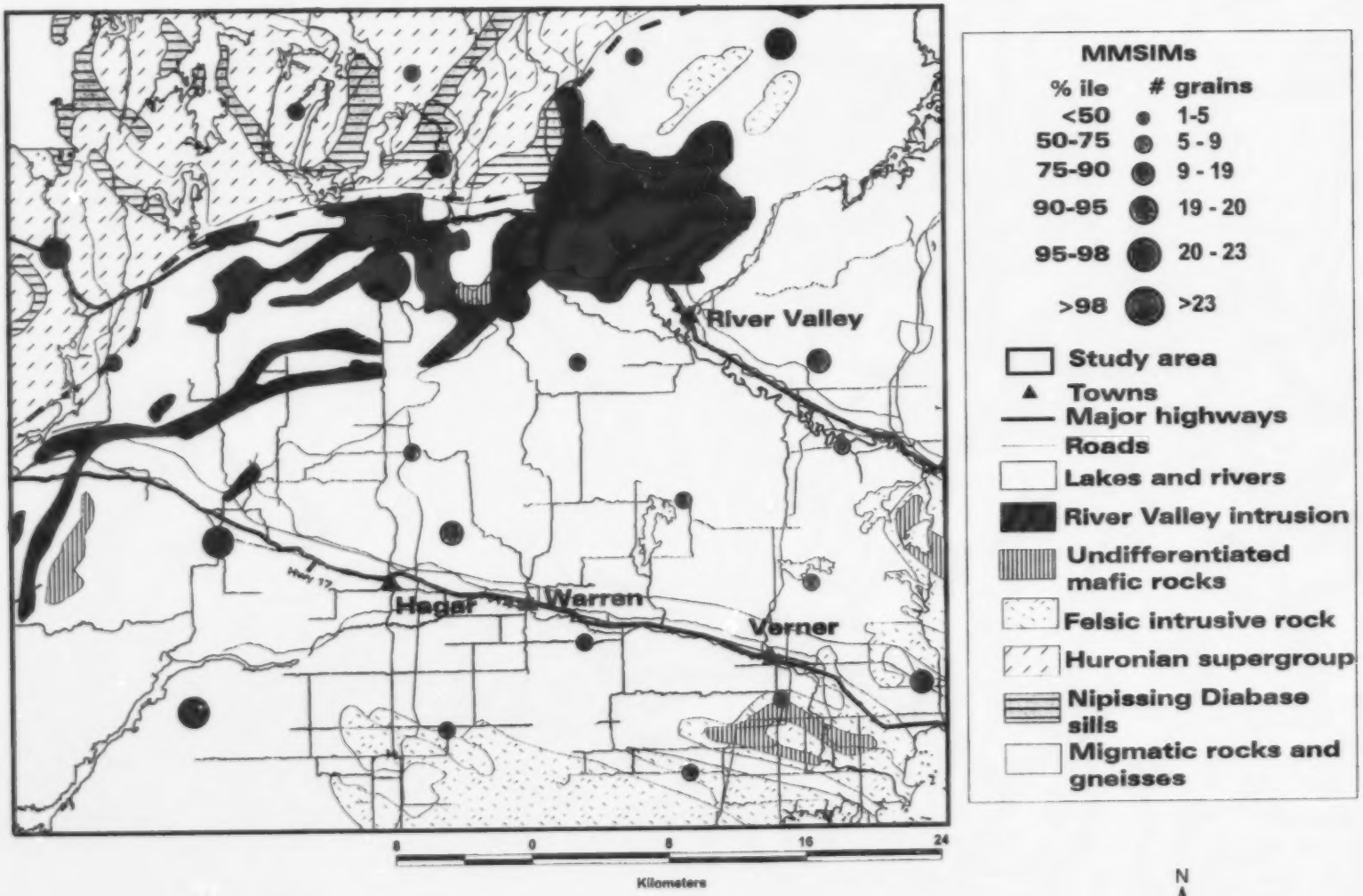


Figure 50: Regional distribution of MMSIMs.

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References

Activation Laboratories Ltd. 1999. 1999 Fee Schedule; p.12.

Averill, S.A.1999. The application of heavy indicator mineralogy in mineral exploration, *in* Drift exploration in glaciated terrain, short course manual, Society of Exploration Geochemists, Vancouver, B.C. p.117-132.

Averill, S.A. 1998. Qualifying report on sample proposal; unpublished report, Overburden Drilling Managenent Ltd., 10p.

Bajc, A.F. 1999. Results of regional humus and till sampling in the eastern part of the Shebandowan greenstone belt, northwestern Ontario; Ontario Geological Survey, Open File Report 5993, 92p.

Bajc, A. F. 1993. Geochemical response of surficial media to nickel-copper-platinum group mineralization. North and East ranges, Sudbury Basin; *in* Summary of Field Work and Other Activities 1993. Ontario Geological Survey, Miscellaneous Paper 162, p.183-187.

Barr, H. 1999. Qualifying report on PFN preliminary results, River Valley platinum group metal property, Sudbury, Ontario; press release, Pacific North West Capital Corp., 3p.

Bowins, R. 1999*a*. Qualifying report on Work instructions, Aqua regia; Standard operations procedure manual, unpublished report, Geoscience Laboratories, Sudbury, ON., 2p.

---1999b. Qualifying report on Standard procedure, Gold, Platinum and Palladium preconcentration Lead-Fire assay silver bead or "Prill" collection; Standard operations procedure manual, unpublished report, Geoscience Laboratories, Sudbury, ON., 3p.

---1999c. Qualifying report on Standard procedure, Dissolution of Pb-Fire assay silver prills; Standard operations procedure manual, unpublished report, Geoscience Laboratories, Sudbury, ON., 2p.

---1999d. Qualifying report on Standard operating procedure, ICP determination of gold, platinum and palladium after lead fire assay silver bead preconcentration, Aqua regia; Standard operations procedure manual, unpublished report, Geoscience Laboratories, Sudbury, ON., 2p.

---1999e. Qualifying report on Work instructions, Operation of the ELAN500™ ICP-MS Quantitative Analysis; Standard operations procedure manual, unpublished report, Geoscience Laboratories, Sudbury, ON., 5p.

---1999f. Qualifying report on Standard operating procedure, Trace elemental Analysis, Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES); unpublished report, Geoscience Laboratories, Sudbury, ON., 3p.

Brady, N.C. 1984. The nature and properties of soils. 9th edition., Macmillan, N.Y.

Chapman, J. and Monroe, C.B. 1993. An introduction to statistical problem solving in geography; Wm. C Brown Communications, Inc. Dubuque, IA. p.115.

Cheng, Q., Bonhan-Carter, G.F., Hall, G.E.M. and Bajc, A.F. 1997. Statistical study of trace elements in the soluble organic and amorphous Fe-Mn phases of surficial sediments, Sudbury Basin. 1. Multivariate and spatial analysis; Journal of Geochemical Exploration, V. 59, p.27-46.

Clifton, H.E., Hunter, R.E., Swanson, F.J. and Phillips, R.L. 1969. Sample size and meaningful gold analysis; U.S. Geological Survey Professional Paper 625-C, 17p.

Coker, W.B., Dunn, C.E., Hall, G.E.M., Rencz, A.N . Dilabilo, R.N.W., Spirito, W.A. and Campbell, J.E. 1991. The behaviour of platinum group elements in the surficial environment at Ferguson Lake, N.W.T., Rottenstone Lake, Saskatchewan and Sudbury Ontario, Canada; Journal of Geochemical Exploration, V. 40, p.165-192.

Cook, N.J., Wood, S. A. and Zhang, Y. 1992. Transport and fixation of Au, Pt and Pd around Lac Sheen Cu-Ni-PGE occurrence in Quebec, Canada; Journal of Geochemical Exploration, V.70, p.187-227.

Cook, S.J. and Fletcher, W.K. 1993. Distribution and behaviour of platinum in soils, sediments and waters of the Tulameen ultramafic complex, southern British Columbia, Canada; Journal of Geochemical Exploration, V.46, p.309-324.

Dawson, J.B. and Stephens, W.E. 1975. Statistical classification of garnets from kimberlite and associated xenoliths, Journal of Geology, V.83, no.5, p.589-607.

Dilabilo, R.N.W. 1988. Residence sites of gold, PGE and rare lithophile elements in till; *in* Prospecting in areas of Glaciated Terrain 1988, The Canadian Institute of Mining and Metallurgy, p.121-140.

Easton, R.M. and Hrominchuk, J. 1999. Project Unit 99-07. Geology and Copper-Platinum Group Element mineral potential of Dana and Crerar Townships, River Valley area, Grenville Province; *in* Summary of Field Work and Other Activities, Ontario Geological Survey, Open File Report 6000, p.30-1 to 30-36.

Fipke, C.E., Gurney, J.J. and Moore, R.O. 1995. Diamond exploration techniques emphasizing indicator mineral geochemistry and Canadian examples, Geological Survey of Canada Bulletin 423, 86p.

Fletcher, W.K. 1988. Preliminary investigation of platinum content of soils and sediments, southern British Columbia; *in* British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, Paper 1989-1, p. 607-611.

Fuchs, W.A. and Rose A.W. 1974. The geochemical behaviour of platinum and palladium in the weathering cycle in the Stillwater Complex, Montana; Economic Geology, V.69, p.332-346.

Gleeson, C.F. and Sheehan, D.G. 1987. Humus and till geochemistry over the Doyon, Bousquet and Williams gold deposits; CIM Bulletin. V.80, No. 898, p.58-66.

Gunn, A.G. 1989. Drainage and overburden geochemistry in exploration for platinum-group element mineralisation in the Unst ophiolite, Shetland; U.K. Journal of Geochemical Exploration, V.31, p.209-236.

Gurney, J.J. 1984. A correlation between garnets and diamonds in kimberlite; *in* Kimberlite Occurrence and Origin: A Basis for conceptual Models in Exploration, University of Western Australia, Perth, Western Australia, publication no. 8, p.143-166.

Gurney, J.J. and Moore, R.O. 1991. Kimberlite garnet, chromite and ilmentite compositions, applications to exploration; *in* P.Sheahan and Achater (Editors), Diamonds: exploration, sampling and evaluation; Prospectors and Developers Association of Canada, Toronto, p.109-146.

Harris, J.F. 1982. Sampling and analytical requirements for effective use of geochemistry in exploration for gold; *in* Precious Metals in the Northern Cordillera, Association of Exploration Geochemists. p.53-67.

Hall, G.E.M. and Bonham-Carter, G.F. 1988. Review of methods to determine gold, platinum and palladium in production-oriented geochemical laboratories, with application of a statistical procedure to test for bias, Journal of Geochemical Exploration. V.30, p.255-286.

Hrominchuk, J. 1999. PU99-07: Geology, stratigraphy and copper-platinum group element mineralization of the River Valley intrusion, Dana Township; *in* Summary of Field Work and Other Activities, Ontario Geological Survey, Open File Report 6000, p. 31-1 to 31-9.

Lalonde, J.P., Bernier, L., Choinier, J. and Hebert, C. 1994. Dispersion of gahnite from the Montauban and Lac Dussault polymetallic deposits, Portneuf Township, Quebec; Ministere des Ressources Naturelles, Secteur des Mines, MB 94-41, 39p.

Lumbers, S.B. 1975. Geology of the Burwash area, Districts of Nippising, Parry Sound, and Sudbury; Ontario Geological Survey, Geological Report 116, p.112.

McCallum, M.E. and Vos, W.P. 1993. Ilmenite signatures: utilization of paramagmatic and geochemical properties in kimberlite exploration; *in* Diamonds: exploration, sampling and evaluation, proceedings of a short course presented by the Prospectors and Developers Association of Canada, Toronto, Ontario, 1993, p.109-146.

McClenaghan, M.B. 1992. Surface till geochemistry and implications for exploration, Black River-Matheson area, northeastern Ontario; Exploration and Mining Geology, V.1, number 4, p.327-337.

Mountain, B.W. and Wood, S. A. 1988. Chemical controls on the solubility, transport, and deposition of platinum and palladium in hydrothermal solutions: a thermodynamic approach; Economic Geology, V.83, p.492-510.

Morris, T.F. and Kaszycki, C.A. 1997. Prospector's guide to drift prospecting for diamonds, northern Ontario; Ontario Geological Survey, Miscellaneous Paper 167, 63p.

Morris, T.F., Sage, R.P., Ayer, J.A., Crabtree, D.C. 2000, in press. Clinopyroxene as an indicator of kimberlite; Ontario Geological Survey, Open File Report.

Morris, T.F., Sage. R.P. and Ayer, J.A. 1999. Cr-diopside and an indicator of kimberlite: application to overburden studies; *in* Geological Association of Canada and Mineralogical Association of Canada Joint Annual Meeting, Sudbury 1999, Abstract V.24, p.86.

Ontario Geological Survey, 1991. Bedrock geology of Ontario, southern sheet: Ontario Geological Survey, Map 2544, scale 1: 1 000 000.

Ottemann, J. and Augustithis, S.S. 1967. Geochemistry and origin of "platinum nuggets" in lateritic covers, ultrabasic rocks and birbirites of Western Ethiopia; Mineral Deposita, V.1, p.269-277.

Parr, J. 1992. A gahnite-garnet retrograde reaction from the Pinnacles deposit, Broken Hill, New South Whales, Australia, Canadian Mineralogist, v.30, p.145-152.

Riese, W.C. and Arp, G.K. 1986. Biogeochemical exploration for platinum deposits in the Stillwater Complex, Montana; Mineral Exploration, Biological Systems and Organic Matter, V.5, p.171-182.

Sage, R.P. 1991. Alkalic rock, carbonatite and kimberlite complexex of Ontario, Superior Province; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 1, p.683-709.

Stephenson, D.M., Morris, T.F. and Crabtree, D.C. 1999. Kimberlite, base metal and gold exploration targets based upon heavy mineral data derived from surface materials, Opasatika Lake Area, northeastern Ontario; Ontario Geological Survey, Open File Report 5982, 66p.

Tardif, N. 2000. Till, B-horizon soils and humus compositional database, River Valley area, Northeastern Ontario; Ontario Geological Survey, Miscellaneous Release-Data 53.

Tardif, N. 1999. Project unit 99-024. Quaternary geology and regional humus and till sampling of the River Valley area, east of Sudbury, Ontario; *in* Summary of Field Work and Other Activities, Ontario Geological Survey, Open File Report 6000, p.37-1 to 37-5.

Wagner, P.A. 1929. The platinum deposits and mines of South Africa; Edinburgh, Oliver and Boyd, 326p.

Wood, S.A. and Vlassopoulos, D. 1990. The dispersion of Pt, Pd and Au in surficial media about two PGE-Cu-Ni prospects in Quebec; Canadian Mineralogist, V.28, p.649-663.

Appendix A-1: Sample locations by UTM coordinates.

Sample #		UTM East	UTM North
99-NPT-00	1	559153	5148532
99-NPT-00	2	568675	5173089
99-NPT-00	3	567936	5175486
99-NPT-00	4	571909	5165788
99-NPT-00	5	566856	5163945
99-NPT-00	6	565688	5174038
99-NPT-00	7	567609	5170798
99-NPT-00	8	564870	5170438
99-NPT-00	9	567573	5166416
99-NPT-0	10	572361	5170942
99-NPT-0	11	568588	5161403
99-NPT-0	12	571088	5161218
99-NPT-0	13	556121	5145058
99-NPT-0	14	559333	5144697
99-NPT-0	15	561788	5145599
99-NPT-0	16	574360	5158673
99-NPT-0	17	570923	5155385
99-NPT-0	18	570023	5156922
99-NPT-0	19	564197	5161259
99-NPT-0	20	566890	5153584
99-NPT-0	21	566561	5157861
99-NPT-0	22	556540	5148874
99-NPT-0	23	556087	5152349
99-NPT-0	24	575904	5138083
99-NPT-0	25	576198	5142170
99-NPT-0	26	576646	5146045
99-NPT-0	27	576303	5149642
99-NPT-0	28	573470	5166006
99-NPT-0	29	560716	5166473
99-NPT-0	30	560199	5168738
99-NPT-0	31	559149	5167226
99-NPT-0	32	559643	5162827
99-NPT-0	33	556202	5165233
99-NPT-0	34	554555	5166537
99-NPT-0	35	554303	5171285
99-NPT-0	36	559349	5174826
99-NPT-0	37	571148	5169155
99-NPT-0	38	556258	5145243
99-NPT-0	39	562026	5160222
99-NPT-0	40	555316	5160349
99-NPT-0	42	544723	5145421
99-NPT-0	41	544596	5141992
99-NPT-0	43	544656	5150443
99-NPT-0	44	544371	5159176
99-NPT-0	45	544658	5162158
99-NPT-0	46	527682	5167514
99-NPT-0	47	528318	5169391
99-NPT-0	48	529943	5172350
99-NPT-0	49	544129	5164467
99-NPT-0	50	534579	5169009
99-NPT-0	51	532936	5170349

Sample #		UTM East	UTM North
99-NPT-0	52	535818	5171360
99-NPT-0	53	539526	5171782
99-NPT-0	54	539007	5167919
99-NPT-0	55	543299	5170296
99-NPT-0	56	542934	5166938
99-NPT-0	57	544468	5165980
99-NPT-0	58	548045	5135511
99-NPT-0	59	552901	5135793
99-NPT-0	60	549741	5138298
99-NPT-0	61	546996	5138978
99-NPT-0	62	552383	5139026
99-NPT-0	63	552652	5141185
99-NPT-0	64	550235	5142150
99-NPT-0	65	551137	5149026
99-NPT-0	66	553264	5145298
99-NPT-0	67	554313	5147669
99-NPT-0	68	552627	5152781
99-NPT-0	69	548437	5147052
99-NPT-0	70	546162	5151802
99-NPT-0	71	550173	5161652
99-NPT-0	72	552077	5160514
99-NPT-0	73	551911	5158136
99-NPT-0	74	551319	5165914
99-NPT-0	75	551216	5177138
99-NPT-0	76	525436	5163611
99-NPT-0	77	536586	5166372
99-NPT-0	78	534946	5164258
99-NPT-0	79	547924	5168334
99-NPT-0	80	547924	5168564
99-NPT-0	81	547016	5170432
99-NPT-0	82	546343	5173927
99-NPT-0	83	567646	5157127
99-NPT-0	84	563979	5130152
99-NPT-0	85	567331	5143375
99-NPT-0	86	567498	5147133
99-NPT-0	87	568039	5150127
99-NPT-0	88	571345	5151947
99-NPT-0	89	561889	5156650
99-NPT-0	90	554882	5155126
99-NPT-0	91	555923	5156952
99-NPT-0	92	562046	5148839
99-NPT-0	93	564110	5147421
99-NPT-0	94	567796	5152392
99-NPT-0	95	569470	5143993
99-NPT-0	96	573014	5149366
99-NPT-0	97	572603	5145113
99-NPT-0	98	570225	5139991
99-NPT-0	99	560082	5137699
99-NPT-	100	565019	5135922
99-NPT-	101	573880	5134658
99-NPT-	102	567529	5130529

Sample #		UTM East	UTM North
99-NPT-	103	557348	5134208
99-NPT-	104	564218	5139461
99-NPT-	105	562297	5132919
99-NPT-	106	556160	5140595
99-NPT-	107	560887	5140934
99-NPT-	108	561269	5142641
99-NPT-	109	543465	5162621
99-NPT-	110	541584	5156868
99-NPT-	111	538962	5154743
99-NPT-	112	535995	5154996
99-NPT-	113	534803	5157133
99-NPT-	114	536068	5160746
99-NPT-	115	528775	5157145
99-NPT-	116	541945	5150289
99-NPT-	117	541124	5142185
99-NPT-	118	538842	5139706
99-NPT-	119	534791	5146638
99-NPT-	120	532773	5140734
99-NPT-	121	535181	5149535
99-NPT-	122	540317	5138927
99-NPT-	123	540029	5136816
99-NPT-	124	544965	5135462
99-NPT-	125	536752	5133978
99-NPT-	126	533263	5136681
99-NPT-	127	555164	5172275
99-NPT-	128	555517	5172496
99-NPT-	129	555465	5172498
99-NPT-	130	555421	5172497
99-NPT-	131	555326	5172455
99-NPT-	132	555423	5172401
99-NPT-	133	555413	5172344
99-NPT-	134	555411	5172304
99-NPT-	135	555316	5172360
99-NPT-	136	555327	5172404
99-NPT-	137	555325	5172493
99-NPT-	138	555320	5172345
99-NPT-	139	555428	5172264
99-NPT-	140	555321	5172264
99-NPT-	141	555420	5172218
99-NPT-	142	555321	5172216
99-NPT-	143	555419	5172173
99-NPT-	144	555324	5172175
99-NPT-	145	555391	5172074
99-NPT-	146	555377	5172124
99-NPT-	147	555322	5172125
99-NPT-	148	555414	5172025
99-NPT-	149	555404	5171850
99-NPT-	150	555323	5172305
99-NPT-	151	555358	5172582
99-NPT-	152	555325	5172544
99-NPT-	153	555423	5172452

Sample #		UTM East	UTM North
99-NPT-	154	559178	5167241
99-NPT-	155	555321	5171833
99-NPT-	156	555326	5171777
99-NPT-	157	555422	5171782
99-NPT-	158	555323	5171674
99-NPT-	159	555421	5171676
99-NPT-	160	555421	5171471
99-NPT-	161	555016	5172639
99-NPT-	162	555263	5172302
99-NPT-	163	535081	5145252
99-NPT-	164	530886	5138393
99-NPT-	165	530643	5142079
99-NPT-	166	559156	5167320
99-NPT-	167	559153	5167274
99-NPT-	168	559141	5167181
99-NPT-	169	559134	5167121
99-NPT-	170	559125	5167067
99-NPT-	171	559119	5167018
99-NPT-	172	559113	5166965

Appendix B: Summary gold grain data.

Summary List of Abbreviations

PPB: parts per billion
PGMs: Platinum group minerals
Reshap/Tot : Reshaped/Total
Mod+Pris/Tot: Modified+Pristine/Total

Regional Sampling

Sample	Number of Visible Gold Grains				Ratio		Total PPB	Other
#	Total	Reshaped	Modified	Pristine	Reshap/Tot	Mod+Prist/Tot	Calculated	Cinnabar
1	11	11	0	0	100	0	147	0
2	1	1	0	0	100	0	2	0
3	9	7	1	1	78	22	115	0
5	3	3	0	0	100	0	5	0
6	14	13	0	1	93	7	2641	0
7	0	0	0	0	0	0	0	0
8	6	5	0	1	83	17	947	0
9	25	23	1	1	92	8	1011	0
10	13	11	1	1	85	15	336	0
11	29	27	2	0	93	7	1285	0
12	21	20	1	0	95	5	210	0
13	9	7	2	0	78	22	146	0
14	5	4	1	0	80	20	39	0
15	11	11	0	0	100	0	48	0
16	8	8	0	0	100	0	17	0
17	6	5	1	0	83	17	72	0
18	8	8	0	0	100	0	12	0
20	2	2	0	0	100	0	30	0
21	8	7	1	0	88	13	24	0
22	9	9	0	0	100	0	20	0
23	11	11	0	0	100	0	126	0
24	7	5	2	0	71	29	574	0
25	0	0	0	0	0	0	0	0
26	1	1	0	0	100	0	4	0
27	0	0	0	0	0	0	0	0
28	3	3	0	0	100	0	134	0
29	0	0	0	0	0	0	0	0
30	6	6	0	0	100	0	70	0
32	4	4	0	0	100	0	50	0
33	1	1	0	0	100	0	5	0
34	3	1	0	2	33	67	5	0
35	0	0	0	0	0	0	0	0
36	14	7	4	3	50	50	10	0
37	4	4	0	0	100	0	152	0
38	5	5	0	0	100	0	225	0
39	1	1	0	0	100	0	5	0
40	4	1	3	0	25	75	25	0
41	4	3	0	1	75	25	22	0
42	2	1	1	0	50	50	121	0
43	2	1	0	1	50	50	30	0
44	0	0	0	0	0	0	0	0
45	14	11	3	0	79	21	7	0
46	1	1	0	0	100	0	2	0
47	3	2	1	0	67	33	1359	0
48	4	1	3	0	25	75	654	0
49	6	0	6	0	0	100	61	0
50	12	12	0	0	100	0	84	0
51	6	3	3	0	50	50	46	0

Sample	Number of Visible Gold Grains				Ratio		Total PPB	Other
#	Total	Reshaped	Modified	Pristine	Reshap/Tot	Mod+Prist/Tot	Calculated	Cinnabar
52	6	5	0	1	83	17	62	0
53	7	3	2	2	43	57	8	0
54	15	6	7	2	40	60	414	0
55	7	6	0	1	86	14	32	0
56	11	10	1	0	91	9	29	0
57	8	7	1	0	88	13	88	0
58	7	5	1	1	71	29	20	0
59	17	16	1	0	94	6	268	0
60	9	9	0	0	100	0	81	0
61	14	13	0	1	93	7	143	0
62	11	10	1	0	91	9	88	0
63	15	11	3	1	73	27	369	0
64	7	6	0	1	86	14	157	0
65	1	1	0	0	100	0	1	0
66	7	6	0	1	86	14	19	0
67	9	4	3	2	44	56	42	0
68	2	1	0	1	50	50	3	0
69	5	4	0	1	80	20	6	0
70	11	8	3	0	73	27	30	0
71	10	8	2	0	80	20	934	0
72	5	5	0	0	100	0	11	0
73	8	8	0	0	100	0	30	0
74	1	1	0	0	100	0	32	0
75	5	4	0	1	80	20	22	10
76	8	5	3	0	63	38	31	0
77	7	6	0	1	86	14	40	1
78	6	6	0	0	100	0	233	0
79	11	9	0	2	82	18	94	1
80	4	4	0	0	100	0	29	0
81	9	8	0	1	89	11	220	10
82	2	2	0	0	100	0	18	0
83	0	0	0	0	0	0	0	0
84	1	1	0	0	100	0	42	0
85	6	6	0	0	100	0	159	0
86	1	1	0	0	100	0	0	0
87	8	7	0	1	88	13	150	0
88	0	0	0	0	0	0	0	0
89	3	3	0	0	100	0	56	0
90	1	0	1	0	0	100	0	0
91	1	1	0	0	100	0	2	0
92	3	3	0	0	100	0	4	0
93	3	3	0	0	100	0	12	0
94	3	3	0	0	100	0	66	0
95	8	8	0	0	100	0	3	0
96	8	8	0	0	100	0	209	0
97	3	3	0	0	100	0	46	0
98	3	3	0	0	100	0	36	0
99	6	6	0	0	100	0	49	0
100	0	0	0	0	0	0	0	0

Sample	Number of Visible Gold Grains				Ratio		Total PPB	Other
#	Total	Reshaped	Modified	Pristine	Reshap/Tot	Mod+Prist/Tot	Calculated	Cinnabar
101	7	7	0	0	100	0	79	0
102	3	1	1	1	33	67	37	0
103	11	10	1	0	91	9	22	0
104	1	1	0	0	100	0	1	0
105	7	7	0	0	100	0	5	0
106	2	2	0	0	100	0	13	0
107	4	4	0	0	100	0	15	0
108	9	9	0	0	100	0	32	0
109	4	4	0	0	100	0	24	0
110	10	10	0	0	100	0	29	0
111	3	3	0	0	100	0	25	0
112	3	3	0	0	100	0	4	0
113	7	6	1	0	86	14	9	0
114	11	11	0	0	100	0	51	0
115	9	9	0	0	100	0	3	0
116	4	4	0	0	100	0	13	0
117	8	7	0	0	88	0	11	0
118	13	12	1	0	92	8	253	0
119	6	6	0	0	100	0	4	0
120	4	3	1	0	75	25	32	0
121	5	5	0	0	100	0	11	0
122	6	5	1	0	83	17	140	0
123	8	6	2	0	75	25	136	0
124	8	7	1	0	88	13	43	0
125	14	13	1	0	93	7	37	0
126	0	0	0	0	0	0	0	0
154	12	11	0	1	92	8	23	0
163	13	13	0	0	100	0	22	0
164	6	5	1	0	83	17	13	0
165	6	6	0	0	100	0	22	0
Total	204	190	11	2				0
Avg	6.8	6.3	0.4	0.1			36.9	

95th percentile for total gold grains	=	**26.7**
95th percentile for pristine gold grains	=	**3.6**
95th percentile for reshaped gold grains	=	**22.6**
95th percentile for modified gold grains	=	**3**

Case Study #1: Dana Lake Zone

Sample	Number of Visible Gold Grains				Ratio		Total PPB	PGMs	
#	Total	Reshaped	Modified	Pristine	Reshap/Tot	Mod+Prist/Tot	Calculated	Sperrylite	Stibiopalladinite
127	15	12	2	1	80	20	53	0	0
128	5	5	0	0	100	0	46	0	0
129	17	11	0	6	65	35	48	0	0
130	11	9	0	2	82	18	281	0	0
131	7	6	1	0	86	14	130	0	0
132	9	7	0	2	78	22	346	0	0
133	31	31	0	0	100	0	323	0	0
134	8	8	0	0	100	0	172	0	0
135	23	20	3	0	87	13	78	0	0
136	12	10	1	1	83	17	27	0	0
138	18	9	6	3	50	50	45	0	1
139	16	12	2	2	75	25	55	0	0
140	13	12	1	0	92	8	181	0	0
141	26	19	3	4	73	27	126	0	0
142	29	27	2	0	93	7	423	0	0
143	12	11	1	0	92	8	327	0	0
144	11	8	3	0	73	27	117	2	0
145	21	13	0	8	62	38	60	0	0
146	13	9	0	4	69	31	231	0	0
147	19	16	0	3	84	16	931	1	0
148	12	9	0	3	75	25	612	2	0
149	23	14	5	4	61	39	351	0	0
150	14	12	0	2	86	14	796	0	0
151	21	18	1	2	86	14	166	0	0
152	27	20	4	3	74	26	827	0	0
153	8	7	1	0	88	13	104	0	0
155	46	30	6	10	65	35	1408	4	0
156	10	7	0	3	70	30	32	0	0
157	28	22	2	4	79	21	112	0	0
158	15	12	0	3	80	20	113	0	0
159	9	8	1	0	89	11	233	3	0
160	9	6	3	0	67	33	115	2	0
161	33	27	1	5	82	18	139	0	0
162	36	29	2	5	81	19	150	0	0
Total	607	476	51	80				14	1

Case Study #2: Azen Creek Zone

Sample	Number of Visible Gold Grains				Ratio		Total PPB	PGMs	
#	Total	Reshaped	Modified	Pristine	Reshap/Tot	Mod+Prist/Tot	Calculated	Sperrylite	Stibiopalladinite
31	1	0	0	1	0	100	0	0	0
166	31	30	0	1	97	3	145	0	0
167	10	10	0	0	100	0	9	0	0
168	15	14	1	0	93	7	157	0	0
169	44	36	5	3	82	18	170	0	0
170	11	10	1	0	91	9	80	1	0
171	10	10	0	0	100	0	20	1	0
172	9	9	0	0	100	0	11	0	0
Total	131	119	7	5				2	0

Appendix C: Kimberlite indicator mineral data.

Summary List of Abbreviations

GP Purple Garnet
GO Orange mantle garnet
DC Chrome diopside
IM Mg-ilmenite
CR Chromite
FO Forsterite
(Numbers in brackets are an estimated number of grains based on observations during heavy mineral picking)

	KIM COUNT (* species not rigorously picked; excluded from total)																		Pseudo-KIMs			
	1.0 to 2.0 mm						0.5 to 1.0 mm						0.25 to 0.5 mm									
Sample #	GP	GO	DC	IM	CR	FO*	GP	GO	DC	IM	CR	FO*	GP	GO*	DC	IM*	CR	FO*	Total KIMs	Cr-diopside	IM	Mn almandine	Total KIMs
003	0	0	0	0	0	0	0	0	0	1	1	0	3	1	0	4(10)	1	0	6	0	0	0	6
018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	3	0	0	0	3
024	0	0	0	0	0	0	0	0	0	1	0	0	3	0	1	0	0	0	5	1	0	0	6
031	0	0	0	0	0	0	1	0	0	3	0	0	3	1	0	0	2	0	9	4	1	0	14
036	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4(10)	0	11	1	0	0	12
045	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	0	0	3
053	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	5	0	0	6
058	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	6	0	0	7
069	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	0	0	3
070	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	1	0	4	2	0	0	6
076	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	11(20)	0	21	1	0	0	22
078	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2	0	0	3
080	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	4	5	0	0	9
082	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	4	0	0	5
083	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
088	0	0	0	1	0	0	0	0	0	0	0	0	3	1	0	0	0	0	4	9	0	0	13
091	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1
092	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	4	0	0	0	4
095	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	1	3	0	0	0	3
105	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	4	0	0	6
106	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	9	0	0	10
115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	2
119	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	2	4
126	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	3	5	0	2	10
034	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2	11	0	3	16
072	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	4	1	0	5	10
112	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2	1	0	0	3
114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	3	1	1	0	1	0	5	6	0	0	11
129	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3
145	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	2	0	5	1	0	0	6
156	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2	0	3	2	0	0	5

Appendix D: Metamorphic massive sulphide indicator mineral data.

(Numbers in brackets are an estimated number of grains based on observations during heavy mineral picking)

Sample #	Metamorphic massive sulphide indicator minerals (MMSIMs)										
	Fayalite	gahnite	Cr-kyanite	Red Rutile	Bronzite	Spessartine	Chalcopyrite	Pyrite	Chromite	Cr-diopside	Total MMSIMs
003	5	0	0	2	3	0	0	0	1	0	11
018	0	0	0	1	0	3	0	0	1	1	6
024	0	0	0	2	0	0	6	0	0	1	9
031	0	0	0	3	0	0	6	7	2	2	20
034	0	0	0	1	0	4	4	0	1	10	20
036	0	0	0	0	0	0	0	0	4	1	5
045	0	0	0	28 (200)	0	0	0	0	0	1	29
053	0	0	0	0	0	0	0	0	0	5	5
058	0	0	0	3	0	0	0	0	0	1	4
069	0	0	0	6	0	0	0	0	0	1	7
070	0	0	0	1	0	0	0	0	0	2	3
072	0	0	0	14	0	5	0	0	0	1	20
076	0	0	0	2	0	0	0	0	8	1	11
078	0	0	0	1	0	0	0	0	0	2	3
080	0	0	0	3	0	0	0	0	0	4	7
082	0	0	0	0	0	0	0	0	0	4	4
083	0	0	0	1	0	0	0	0	0	0	1
088	0	0	0	2	0	0	0	0	0	0	2
091	0	0	0	4	0	0	0	0	0	0	4
092	0	0	0	2	0	0	0	0	0	2	4
095	0	0	0	4	0	0	0	0	0	0	4
105	0	0	0	1	0	0	0	0	0	0	1
106	0	0	0	4	0	0	0	0	0	1	5
112	0	0	1	7	0	0	0	0	0	1	9
114	0	0	0	8	0	0	0	0	0	0	8
115	0	0	0	4	0	0	0	0	0	0	4
119	0	1	0	9	0	0	0	0	0	0	10
126	0	0	0	9	0	0	0	0	0	1	10
128	0	0	0	1	0	0	0	0	1	6	8
129	0	0	0	0	0	0	0	0	0	3	3
145	0	0	0	0	0	0	0	0	1	0	1
156	0	0	0	0	0	0	0	0	2	2	4
Total	5	1	1	123	3	12	16	7	21	53	242

Appendix J1: Quality control chart, ICP-MS lead fire assay: C-horizon till, B-horizon soils, humus and non-ferromagnetic heavy minerals.

Quality Control Data: ICP-MS Fire Assay - C-horizon Till + B-Horizon Soil + Humus + Non-ferromagnetic fraction

C-Horizon Till

Element	Method	MDL	Duplicate Data		Internal Standard			Till-1			Till-4	
		(ppb)	N	Precision (+/-)	N	Mean (ppb)	SD (ppb)	N	Mean (ppb)	Sd (ppb)	N	Mean (ppb)	Sd (ppb)
Au	Fire Assay	0.6	9	4	4	18.6	15.1	2	8.3	5.1	2	8.4	5.577
Pt	Fire Assay	0.3	9	7	4	3	3.7	2	3.4	3.6	2	3.1	n/a
Pd	Fire Assay	0.7	9	6	4	2.2	2.5	2	0.9	0.6	2	1.8	1.694

B-Horizon Soils

Element	Method	MDL	Duplicate Data		Internal Standard			Till-1		Till-4	
		(ppb)	N	Precision (+/-)	N	Mean (ppb)	SD (ppb)	N	Mean (ppb)	N	Mean (ppb)	Sd (ppb)
Au	Fire Assay	0.6	5	4.5	3	30.1	8.196	1	8.8	2	5.8	1.952
Pt	Fire Assay	0.3	5	0.2	3	1	0.095	1	1.9	2	n/a	n/a
Pd	Fire Assay	0.7	5	0.5	3	0.8	0.248	1	0.6	2	n/a	n/a

Humus

Element	Method	MDL	Duplicate Data		Internal Standard			Lake Sed. 1			Lake Sed 4	
		(ppb)	N	Precision (+/-)	N	Mean (ppb)	SD (ppb)	N	Mean (ppb)	Sd (ppb)	N	Mean (ppb)	Sd (ppb)
Au	Fire Assay	4	9	15	4	n/a	n/a	2	n/a	n/a	2	n/a	n/a
Pt	Fire Assay	0.4	9	2	4	1.1	0.29	2	2.2	2.85	2	0.9	0.11
Pd	Fire Assay	0.4	9	2	4	n/a	n/a	2	1.3	1.58	2	n/a	n/a

Non-ferromagnetic fraction

Element	Method	MDL	Duplicate Data		Standards	
		(ppb)	N	Precision (+/-)	N	Mean (ppb)	SD (ppb)
Au	Fire Assay	0.6	8	120	7	96	12.111
Pt	Fire Assay	0.3	8	1.5	7	561	28.954
Pd	Fire Assay	0.7	8	1	7	350	25.283

Notes:
MDL: method detection limit
ppb: parts per billion
N: number of duplicates or standards
Precision: precision derived from X,Y precision control charts
SD: standard deviation
n/a: value not calculated due to most samples containing less than detectable levels of that element

Appendix K1: Geochemistry of C-horizon till, B-horizon soils and humus by ICP-MS lead fire assay.

Summary List of Abbreviations

D.L.: Detection Limit
ppb: parts per billion
ND: Not Detected

B-Horizon soils

Element	Au (ppb)	Pt (ppb)	Pd (ppb)	Au+Pt+Pd
D.L.	0.6	0.3	0.7	ppb
071B	3.5	2.4	2.3	8.2
072B	3.0	1.8	1.2	6.0
073B	4.1	3.7	2.1	9.9
074B	6.9	1.1	1.0	9.0
075B	17.9	0.7	0.6	19.2
076B	2.6	0.7	0.6	3.9
077B	14.4	1.4	0.8	16.6
078B	2.7	1.3	1.1	5.2
079B	1.2	1.0	1.0	3.2
080B	1.2	1.4	0.7	3.3
081B	2.1	1.1	0.8	4.0
082B	1.1	0.8	ND	1.9
083B	2.0	0.7	1.0	3.7
084B	2.3	0.9	0.7	3.9
085B	14.1	1.4	0.9	16.4
086B	1.4	1.1	0.9	3.4
087B	8.8	1.0	1.1	11.0
088B	1.6	1.0	1.2	3.9
089B	15.1	1.6	1.7	18.4
090B	2.1	1.4	1.3	4.8
091B	1.7	2.3	2.0	6.0
092B	3.3	0.9	0.9	5.0
093B	6.0	0.7	0.9	7.6
094B	3.0	0.7	1.0	4.8
095B	4.3	1.3	1.5	7.1
096B	3.5	1.2	1.7	6.4
097B	11.1	1.0	0.9	13.0
098B	5.6	0.7	1.2	7.4
099B	7.3	0.7	1.2	9.2
100B	3.3	0.9	1.1	5.4
101B	2.3	0.9	1.2	4.4
102B	2.6	1.0	1.9	5.6
103B	2.3	0.9	1.3	4.5
104B	6.1	0.7	1.1	7.9
105B	5.8	1.1	1.2	8.1
106B	2.3	0.9	1.5	4.7
107B	60.5	0.9	0.9	62.3
108B	10.0	1.9	2.9	14.7
109B	3.1	5.1	4.7	12.9
110B	8.3	1.4	1.2	10.9
111B	2.9	6.8	3.4	13.1
112B	4.0	3.6	3.2	10.8
113B	12.8	1.3	1.3	15.3
114B	10.6	1.5	1.3	13.5
116B	3.6	2.0	2.1	7.7
117B	3.5	1.7	1.7	6.9
118B	22.3	1.9	1.9	26.0
119B	22.7	2.0	1.8	26.5

Element	Au (ppb)	Pt (ppb)	Pd (ppb)	Au+Pt+Pd
D.L.	0.6	0.3	0.7	ppb
120B	2.4	1.4	1.7	5.5
121B	2.0	1.7	1.3	4.9
122B	3.6	2.2	1.8	7.6
123B	3.0	1.5	1.6	6.1
124B	4.1	1.3	1.4	6.8
125B	3.6	1.8	1.8	7.1
126B	2.7	1.5	1.1	5.3
127B	6.4	2.0	2.2	10.5
128B	4.1	4.2	1.2	9.5
129B	7.0	1.6	1.3	9.9
130B	0.9	1.1	0.8	2.8
131B	3.9	3.9	15.2	23.0
132B	4.3	1.5	5.9	11.7
133B	23.1	1.1	1.2	25.4
134B	4.2	1.6	1.9	7.7
135B	2.2	2.4	8.2	12.9
136B	6.7	2.1	2.1	10.9
137B	4.1	3.3	10.8	18.2
138B	59.4	7.6	7.3	74.3
139B	5.6	2.5	3.4	11.5
140B	1.9	3.1	5.0	10.1
141B	4.7	4.6	3.2	12.5
142B	27.6	8.4	4.2	40.3
143B	3.4	1.8	2.9	8.1
144B	3.0	1.8	5.4	10.3
145B	5.4	9.0	25.4	39.7
146B	3.8	3.7	1.8	9.4
147B	3.7	2.6	3.5	9.8
148B	8.6	11.5	4.1	24.2
150B	6.5	1.9	7.5	15.9
151B	2.0	1.2	1.8	5.0
152B	3.7	1.1	1.8	6.7
153B	6.0	2.2	1.5	9.6
154B	4.4	1.2	1.4	7.0
155B	1.9	7.8	9.6	19.3
156B	1.8	10.3	6.6	18.7
157B	11.3	4.8	7.3	23.4
158B	5.5	3.5	4.4	13.4
159B	2.4	5.7	3.7	11.8
160B	3.0	2.8	5.4	11.2
161B	3.0	1.1	1.7	5.8
162B	9.8	2.4	2.2	14.4
163B	22.5	1.1	1.4	25.0
164B	3.3	1.0	0.9	5.2
165B	3.0	1.8	1.1	5.9
166B	3.3	1.6	1.9	6.8
167B	11.8	6.2	91.4	109.4
168B	4.3	1.2	1.2	6.7
169B	1.3	0.8	0.9	3.0

Element	Au (ppb)	Pt (ppb)	Pd (ppb)	Au+Pt+Pd
D.L.	0.6	0.3	0.7	ppb
170B	3.4	1.4	1.8	6.6
171B	25.2	1.9	1.3	28.4
172B	11.0	0.9	0.6	12.5

C-Horizon Till

Element	Au (ppb)	Pt (ppb)	Pd (ppb)	Au+Pt+Pd
D.L.	0.6	0.3	0.7	ppb
001M	3.9	1.2	0.6	5.7
002M	14.5	1.5	1.2	17.1
003M	3.7	1.5	1.1	6.3
005M	4.6	1.3	0.9	6.8
006M	35.4	1.3	1.0	37.7
007M	5.3	1.5	1.2	8.0
008M	5.2	1.5	1.1	7.7
009M	27.8	1.5	1.0	30.2
010M	12.1	2.3	3.2	17.5
011M	93.3	1.3	0.7	95.3
012M1	6.1	1.2	1.0	8.3
012M2	12.2	3.3	1.6	17.1
013M	2.9	0.8	ND	3.8
014M	4.3	2.4	3.3	10.0
015M	3.6	1.1	0.6	5.3
016M	2.7	1.2	0.7	4.7
017M	1.8	1.2	0.9	3.9
018M	1.9	0.7	ND	2.6
020M	1.3	1.1	0.6	3.0
021M	22.0	1.2	0.6	23.7
022M	6.8	1.3	1.2	9.4
023M	4.7	1.2	1.7	7.6
024M	5.9	0.8	0.8	7.5
025M	2.6	1.3	1.1	5.0
026M	2.8	1.0	1.0	4.8
027M	16.8	1.0	1.2	19.0
028M	2.4	1.5	1.9	5.8
029M	4.8	1.7	2.5	9.0
030M	6.0	1.6	2.2	9.8
031M	73.5	0.8	0.6	74.9
032M	2.6	0.7	0.5	3.9
033M	4.9	0.7	0.8	6.5
034M	7.9	0.8	0.9	9.6
035M	5.1	1.1	1.3	7.4
036M	8.1	1.3	1.5	10.9
037M	3.2	1.4	1.0	5.6
038M	7.0	2.3	2.1	11.3
039M	3.8	1.6	1.7	7.0
040M	5.5	1.6	2.2	9.3
041M	3.5	1.0	1.2	5.7
042M	19.6	0.8	1.0	21.3

Element	Au (ppb)	Pt (ppb)	Pd (ppb)	Au+Pt+Pd
D.L.	0.6	0.3	0.7	ppb
043M	5.3	2.1	1.8	9.2
044M	3.1	ND	ND	3.1
045M	3.8	1.3	1.6	6.7
046M	5.2	2.1	1.5	8.9
047M	5.2	1.9	2.4	9.5
048M	4.4	1.4	1.4	7.1
049M	5.3	2.1	2.9	10.4
050M	5.3	2.0	3.4	10.7
051M	6.4	11.3	7.7	25.4
052M	2.9	4.6	3.3	10.8
053M	2.8	1.8	1.6	6.3
054M	8.8	1.7	1.2	11.7
055M	3.7	1.8	1.5	7.0
056M	8.7	1.3	1.2	11.1
057M	7.5	1.7	1.8	11.1
058M	11.5	9.0	6.1	26.6
059M	11.9	0.6	0.6	13.1
060M	15.5	5.0	2.3	22.8
061M	19.8	2.1	3.1	25.0
062M	4.5	3.6	5.0	13.1
063M	3.1	5.3	6.6	15.0
064M	4.8	0.9	0.8	6.5
065M	12.5	1.7	1.8	16.1
066M	19.5	1.4	1.6	22.5
067M	3.1	2.3	2.1	7.5
068M	6.7	2.8	1.8	11.2
069M	6.4	2.3	2.0	10.7
070M	9.8	2.0	1.6	13.4
071M	88.8	2.4	2.5	93.7
072M	4.9	4.6	4.2	13.7
073M	1.9	2.9	3.5	8.4
074M	3.5	0.9	1.6	6.0
075M	4.0	3.2	3.1	10.3
076M	3.5	1.8	1.9	7.2
077M	3.5	1.8	1.9	7.2
078M	4.3	1.2	1.5	7.0
079M	5.8	1.4	1.5	8.6
080M	4.7	2.0	2.9	9.6
081M	2.9	1.4	1.8	6.1
082M	2.7	1.1	1.2	5.0
083M	3.1	1.0	1.2	5.3
084M	1.3	0.9	1.0	3.2
085M	6.1	1.3	1.5	8.8
086M	2.0	0.9	0.6	3.5
087M	3.9	1.0	0.7	5.6
088M	18.1	1.2	ND	19.3
089M	6.7	2.1	1.1	9.9
090M	1.5	1.9	1.2	4.6
091M	1.8	1.6	1.5	4.9

Element	Au (ppb)	Pt (ppb)	Pd (ppb)	Au+Pt+Pd
D.L.	0.6	0.3	0.7	ppb
092M	6.2	1.2	3.1	10.5
093M	1.3	1.1	0.7	3.2
094M	2.4	0.9	0.7	4.0
095M	4.1	1.0	0.6	5.8
096M	3.2	0.9	0.8	4.8
097M	1.0	1.1	ND	2.0
098M	5.5	0.7	ND	6.1
099M	4.3	1.6	0.8	6.6
100M	2.8	0.8	0.7	4.3
101M	9.9	0.7	0.8	11.5
102M	11.6	0.8	0.6	13.0
103M	8.2	0.8	0.8	9.8
104M	23.3	0.8	0.7	24.8
105M	19.6	1.2	0.6	21.3
106M	2.9	1.0	1.8	5.6
107M	3.8	0.9	1.0	5.7
108M	1.4	1.1	0.9	3.3
109M	5.9	1.0	0.9	7.8
110M	28.3	0.7	0.9	29.9
111M	6.1	1.1	1.2	8.3
112M	1.4	0.9	0.7	2.9
113M	5.7	5.5	2.1	13.3
114M	4.7	2.3	2.2	9.1
115M	4.9	2.9	1.6	9.4
116M	5.5	1.8	1.7	9.0
117M	3.0	2.4	1.5	6.9
118M	23.5	2.2	1.8	27.6
119M	2.9	2.1	1.1	6.1
120M	3.4	2.0	1.8	7.2
121M	1.7	1.9	1.3	4.9
122M	9.3	2.3	1.8	13.3
123M	2.7	2.5	1.6	6.8
124M	3.0	1.4	1.9	6.3
125M	3.8	1.8	1.7	7.4
126M	10.9	1.5	1.5	13.9
127M	23.0	2.5	2.7	28.2
128M	ND	ND	ND	0.0
129M	4.9	1.5	1.8	8.2
130M	4.8	2.3	1.6	8.7
131M	6.5	4.4	5.4	16.2
132M	5.8	7.3	8.3	21.4
133M	7.0	3.7	5.8	16.5
134M	42.4	0.7	0.7	43.9
135M	182.6	0.7	0.7	184.0
136M	15.0	8.9	20.1	43.9
138M	4.1	2.1	3.3	9.5
139M	2.6	6.6	6.1	15.3
140M	4.4	6.1	3.3	13.8
141M	16.6	4.4	6.5	27.6

Element	Au (ppb)	Pt (ppb)	Pd (ppb)	Au+Pt+Pd
D.L.	0.6	0.3	0.7	ppb
142M	3.9	0.6	1.3	5.8
143M	3.9	1.3	1.1	6.3
144M	7.0	1.7	2.0	10.7
145M	16.6	1.9	1.6	20.1
146M	31.5	218.1	181.1	430.8
147M	ND	ND	0.9	0.9
148M	13.9	1.7	1.5	17.0
149M	10.0	2.5	3.9	16.4
150M	4.9	4.2	5.5	14.6
151M	3.4	2.3	3.3	9.0
152M	12.1	7.3	4.6	24.1
153M	24.7	2.3	2.9	29.9
154M	14.1	3.1	4.9	22.1
155M	4.2	ND	ND	4.2
156M	3.9	ND	ND	3.9
157M	6.1	2.1	2.4	10.6
158M	5.8	2.1	8.9	16.9
159M	7.6	2.4	3.4	13.4
160M	12.2	2.4	2.1	16.7
161M1	7.0	9.5	4.1	20.5
161M2	20.2	6.1	7.5	33.9
162M1	5.2	2.1	2.0	9.2
162M2	12.8	2.4	3.7	18.9
163M	3.0	1.5	1.1	5.6
164M	3.4	1.6	1.0	6.0
165M1	1.8	1.6	1.8	5.2
165M2	20.0	5.7	7.1	32.8
166M	18.4	1.6	2.8	22.9
167M1	6.1	1.8	17.4	25.3
167M2	67.2	3.0	40.9	111.2
168M	7.1	1.9	2.4	11.4
169M1	8.0	1.0	1.4	10.4
169M2	9.8	7.6	8.2	25.5
170M	5.0	2.2	5.2	12.5
171M	5.2	1.5	2.3	9.0
172M	3.1	1.1	1.0	5.2

Humus

Element	Pd ppb	Pt ppb	Au ppb	Pd+Pt+Au
D.L.	0.4	0.4	4	
99 NPT 1 H	4.0	2.9	22	28.74
99 NPT 3 H	1.7	3.4	12	17.56
99 NPT 5 H	2.6	2.0	15	20.04
99 NPT 9 H	2.0	3.6	8	13.64
99 NPT 10 H	10.4	6.6	13	29.47
99 NPT 11 H	9.6	1.8	21	32.17
99 NPT 12 H	12.0	7.8	11	30.31
99 NPT 13 H	2.1	2.0	5	9.51

Element	Pd ppb	Pt ppb	Au ppb	Pd+Pt+Au
D.L.	0.4	0.4	4	
99 NPT 15 H	4.5	3.3	6	14.22
99 NPT 16 H	1.5	1.0	5	7.95
99 NPT 17 H	ND	1.1	ND	1.10
99 NPT 18 H	ND	0.8	5	5.80
99 NPT 21 H	9.7	3.4	8	21.48
99 NPT 22 H	ND	1.8	ND	1.80
99 NPT 23 H	2.7	1.7	ND	0.37
99 NPT 24 H	ND	1.3	ND	1.30
99 NPT 25 H	1.8	1.6	ND	3.41
99 NPT 26 H	ND	1.1	ND	1.10
99 NPT 27 H	ND	1.0	ND	1.00
99 NPT 28 H	11.5	8.1	10	29.85
99 NPT 29 H	7.7	4.8	14	26.30
99 NPT 30 H	15.9	11.8	14	41.61
99 NPT 31 H	15.7	10.3	12	37.63
99 NPT 32 H	5.2	4.8	5	14.67
99 NPT 33 H	6.2	4.6	ND	10.81
99 NPT 34 H	ND	ND	ND	n/a
99 NPT 35 H	2.6	3.7	ND	6.35
99 NPT 36 H	7.0	6.7	8	21.59
99 NPT 37 H	3.7	4.0	17	24.79
99 NPT 38 H	0.9	2.2	ND	3.08
99 NPT 39 H	ND	1.2	12	12.81
99 NPT 40 H	ND	1.7	ND	1.70
99 NPT 41 H	1.4	3.0	ND	0.44
99 NPT 42 H	5.7	6.4	16	28.43
99 NPT 43 H	3.8	5.1	ND	8.86
99 NPT 44 H	5.1	8.1	ND	13.21
99 NPT 46 H	6.2	7.9	ND	14.15
99 NPT 47 H	7.4	8.1	ND	15.53
99 NPT 48 H	1.7	4.8	ND	6.47
99 NPT 49 H	2.5	4.2	ND	6.74
99 NPT 55 H	11.6	12.9	ND	24.47
99 NPT 58 H	1.9	2.3	ND	4.20
99 NPT 59 H	1.7	2.4	ND	4.18
99 NPT 60 H	6.7	5.3	ND	12.05
99 NPT 61 H	0.6	4.1	ND	4.77
99 NPT 62 H	ND	0.6	ND	0.60
99 NPT 63 H	ND	1.4	ND	1.40
99 NPT 65 H	ND	1.0	ND	1.00
99 NPT 66 H	ND	0.9	ND	0.90
99 NPT 68 H	2.0	3.9	ND	5.90
99 NPT 73 H	6.4	9.2	ND	15.60
99 NPT 74 H	8.0	8.2	23	39.24
99 NPT 75 H	11.3	7.3	11	30.05
99 NPT 76 H	85.4	97.6	67	250.40
99 NPT 78 H	9.9	11.8	ND	21.69
99 NPT 79 H	3.8	6.1	ND	9.98
99 NPT 80 H	ND	8.6	ND	8.60

Element	Pd ppb	Pt ppb	Au ppb	Pd+Pt+Au
D.L.	0.4	0.4	4	
99 NPT 81 H	6.8	9.4	ND	16.23
99 NPT 82 H	ND	9.8	5	14.80
99 NPT 84 H	3.5	5.9	ND	9.36
99 NPT 85 H	ND	3.8	ND	3.80
99 NPT 86 H	ND	4.5	ND	4.50
99 NPT 87 H	ND	1.7	ND	1.70
99 NPT 88 H	ND	2.5	ND	2.50
99 NPT 90 H	ND	5.0	ND	5.00
99 NPT 92 H	ND	3.9	ND	3.90
99 NPT 93 H	ND	2.6	ND	2.60
99 NPT 94 H	2.8	6.2	23	31.97
99 NPT 95 H	1.2	4.5	ND	5.67
99 NPT 96 H	ND	1.3	5	6.30
99 NPT 97 H	2.8	11.4	ND	14.22
99 NPT 98 H	ND	1.4	18	19.40
99 NPT 100 H	ND	2.1	ND	2.40
99 NPT 101 H	ND	2.0	ND	2.00
99 NPT 103 H	7.0	8.5	15	30.21
99 NPT 105 H	ND	14.0	ND	14.00
99 NPT 106 H	2.8	12.0	ND	10.78
99 NPT 107 H	ND	1.7	ND	1.70
99 NPT 108 H	ND	4.8	ND	4.80
99 NPT 110 H	2.5	8.3	ND	10.80
99 NPT 111 H	19.3	16.9	9	45.09
99 NPT 12 H	19.7	21.1	12	53.10
99 NPT 114 H	26.7	31.9	18	76.37
99 NPT 115 H	18.4	20.7	8	46.73
99 NPT 117 H	3.0	10.6	ND	13.58
99 NPT 118 H	ND	4.2	ND	4.20
99 NPT 119 H	7.4	19.3	25	51.96
99 NPT 121 H	1.5	5.4	ND	6.90
99 NPT 122 H	ND	1.7	ND	1.70
99 NPT 123 H	ND	5.2	ND	5.20
99 NPT 124 H	ND	2.1	ND	2.10
99 NPT 125 H	ND	4.4	ND	4.40
99 NPT 126 H	1.5	6.1	ND	7.60
99 NPT 127 H	7.6	14.6	ND	22.19
99 NPT 128 H	7.5	32.8	8	48.49
99 NPT 130 H	4.3	8.7	13	26.17
99 NPT 132 H	10.2	16.4	4	30.73
99 NPT 133 H	ND	5.2	ND	5.20
99 NPT 134 H	7.6	14.0	ND	21.61
99 NPT 135 H	9.7	8.2	ND	17.88
99 NPT 136 H	ND	4.7	ND	4.70
99 NPT 137 H	ND	1.9	ND	1.90
99 NPT 138 H	3.8	7.4	ND	11.20
99 NPT 139 H	9.2	13.7	9	31.54
99 NPT 141 H	2.1	5.3	ND	7.36
99 NPT 143 H	3.0	10.0	5	17.88

Element	Pd ppb	Pt ppb	Au ppb	Pd+Pt+Au
D.L.	0.4	0.4	4	
99 NPT 144 H	5.9	8.5	5	19.44
99 NPT 147 H	4.0	9.1	ND	13.13
99 NPT 148 H	8.2	11.7	5	24.62
99 NPT 149 H	11.5	25.5	ND	37.01
99 NPT 153 H	9.2	13.6	7	29.98
99 NPT 154 H	5.5	9.4	ND	14.86
99 NPT 156 H	3.8	7.3	ND	11.04
99 NPT 158 H	6.2	12.1	ND	18.31
99 NPT 159 H	9.1	15.2	10	34.52
99 NPT 160 H	5.9	15.1	4	25.12
99 NPT 162 H	13.4	21.5	8	42.96
99 NPT 163 H	14.6	19.2	8	41.98
99 NPT 164 H	5.9	42.8	ND	48.71
99 NPT 165 H	24.5	25.2	9	58.59
99 NPT 167 H	24.7	33.2	8	65.95
99 NPT 168 H	1.3	5.9	ND	7.24
99 NPT 169 H	ND	3.7	ND	3.70
99 NPT 170 H	5.4	17.4	112	134.53
99 NPT 172 H	8.5	11.8	6	26.65

Appendix K2: Geochemistry of non-ferromagnetic heavy minerals by ICP-MS lead fire assay.

Summary List of Abbreviations

D.L.: Detection Limit
ppb: parts per billion
ND: Not Detected

Element	Au	Pt	Pd	Au+Pt+Pd
D.L.	0.6	0.3	0.7	
	(ppb)	(ppb)	(ppb)	(ppb)
99NPT-001	76	3	3	82
99NPT-002	121	4	4	129
99NPT-003	235	6	28	269
99NPT-005	211	3	2	216
99NPT-006	939	3	3	946
99NPT-007	27	5	12	44
99NPT-008	894	4	8	905
99NPT-009	244	7	5	255
99NPT-010	925	3	3	931
99NPT-011	1268	3	3	1275
99NPT-012	337	3	3	342
99NPT-013	226	7	31	265
99NPT-014	93	7	8	109
99NPT-015	216	3	3	222
99NPT-016	42	2	2	45
99NPT-017	162	3	3	169
99NPT-018	216	2	3	221
99NPT-019	175	2	3	180
99NPT-020	39	3	4	46
99NPT-021	ND	ND	ND	0
99NPT-022	20	7	1	29
99NPT-023	987	4	3	994
99NPT-024	355	3	3	360
99NPT-025	13	0.5	ND	14
99NPT-026	98	4	3	105
99NPT-027	19	3	4	26
99NPT-028	153	6	3	162
99NPT-030	585	4	4	593
99NPT-031	158	9	19	186
99NPT-032	140	6	7	153
99NPT-033	6	8	9	24
99NPT-034	17	7	7	31
99NPT-035	148	5	5	159
99NPT-036	12	6	5	24
99NPT-037	400	4	3	407
99NPT-038	241	30	6	277
99NPT-039	262	3	5	270
99NPT-040	9	19	8	36
99NPT-041	69	7	6	83
99NPT-042	374	5	8	386
99NPT-043	83	6	5	94
99NPT-044	14	9	7	30
99NPT-045	119	9	6	134
99NPT-046	64	3	14	81
99NPT-047	986	3	4	994
99NPT-048	604	3	3	610
99NPT-049	175	5	4	183
99NPT-050	127	2	7	136

Element	Au	Pt	Pd	Au+Pt+Pd
D.L.	0.6	0.3	0.7	
	(ppb)	(ppb)	(ppb)	(ppb)
99NPT-051	215	8	3	226
99NPT-052	240	2	3	245
99NPT-053	140	6	8	154
99NPT-054	310	4	6	320
99NPT-055	72	3	3	79
99NPT-056	130	5	12	147
99NPT-057	58	5	5	68
99NPT-058	599	5	8	612
99NPT-059	206	3	2	211
99NPT-060	689	6	5	701
99NPT-061	249	4	4	257
99NPT-062	137	2	2	142
99NPT-063	63	22	3	87
99NPT-064	264	4	3	272
99NPT-065	92	5	6	103
99NPT-066	102	10	6	117
99NPT-067	247	3	3	253
99NPT-068	249	3	2	254
99NPT-069	91	7	6	105
99NPT-070	124	7	5	136
99NPT-071	367	9	3	379
99NPT-072	151	8	6	164
99NPT-073	119	92	44	255
99NPT-074	37	3	3	43
99NPT-075	20	8	16	44
99NPT-076	92	16	3	111
99NPT-077	32	2	2	36
99NPT-078	553	5	3	561
99NPT-079	49	4	3	57
99NPT-080	331	9	7	347
99NPT-081	366	4	4	374
99NPT-082	66	6	7	79
99NPT-083	2	2	2	5
99NPT-084	3	1	1	5
99NPT-085	106	3	3	112
99NPT-086	18	1	2	21
99NPT-087	97	3	3	102
99NPT-088	4	4	2	11
99NPT-089	656	12	15	683
99NPT-090	8	3	3	14
99NPT-091	3	6	5	14
99NPT-092	4	3	3	10
99NPT-093	32	6	2	41
99NPT-094	57	2	2	61
99NPT-095	2	3	2	7
99NPT-096	188	3	2	193
99NPT-097	81	2	2	84
99NPT-098	148	2	2	152

Element	Au	Pt	Pd	Au+Pt+Pd
D.L.	0.6	0.3	0.7	
	(ppb)	(ppb)	(ppb)	(ppb)
99NPT-099	29	1	1	32
99NPT-100	138	3	3	144
99NPT-101	159	3	2	164
99NPT-102	131	2	2	135
99NPT-103	17.3	2.5	1.5	21
99NPT-104	1.2	2.2	1.4	5
99NPT-105	3	2	2	8
99NPT-106	32	3	3	39
99NPT-107	97.7	2.6	1.6	102
99NPT-108	15.9	2.8	1.8	21
99NPT-109	2	9.9	7.2	19
99NPT-110	2.9	5.7	3.9	13
99NPT-111	1.5	5.2	4	11
99NPT-112	3	6	4	12
99NPT-113	2.5	7.6	3.3	13
99NPT-114	88	6	8	102
99NPT-115	328	20	4	352
99NPT-116	63.2	8.1	5.5	77
99NPT-117	18.5	4.6	3.2	26
99NPT-118	677.1	4.5	3.2	685
99NPT-119	7	8	5	20
99NPT-120	31.4	5	3.3	40
99NPT-121	1.1	3.5	2	7
99NPT-122	19.3	7.5	6	33
99NPT-123	57.7	6.6	5.3	70
99NPT-124	183.6	4.7	3.7	192
99NPT-125	110	6	5	121
99NPT-126	3	5	4	12
99NPT-128	69	5	4	78
99NPT-129	127	12	4	143
99NPT-129	60.2	11.4	12	84
99NPT-130	511.2	7.1	4.8	523
99NPT-131	140.3	6.2	5.4	152
99NPT-132	429.1	6.2	4.9	440
99NPT-133	685.3	6.5	5.2	697
99NPT-134	340.8	7.5	5.8	354
99NPT-135	31.1	8	17.6	57
99NPT-136	324.5	97	33.2	455
99NPT-138	381.5	10.1	8.9	401
99NPT-139	148.4	18.2	63.3	230
99NPT-140	618.2	29.8	87.7	736
99NPT-141	259.5	139.7	168	567
99NPT-142	464.6	32.1	116.8	614
99NPT-143	298.5	53.2	40.1	392
99NPT-144	ND	ND	ND	0
99NPT-145	91	35	14	141
99NPT-146	50.9	32.3	12.9	96
99NPT-147	868.4	7.7	19.8	896

Element	Au	Pt	Pd	Au+Pt+Pd
D.L.	0.6	0.3	0.7	
	(ppb)	(ppb)	(ppb)	(ppb)
99NPT-148	691.7	39.5	322.2	1053
99NPT-149	337.5	83.3	872.5	1293
99NPT-151	277.9	6.1	3.7	288
99NPT-152	918.5	27.2	4.3	950
99NPT-153	118	6.9	4.7	130
99NPT-154	165.4	7.1	5	178
99NPT-155	103.2	22.7	70	196
99NPT-156	32	45	44	121
99NPT-157	114.5	59.4	134.8	309
99NPT-158	115.2	13.4	80	209
99NPT-159	1233.7	16.3	160.4	1410
99NPT-160	835.9	1014	181.8	2032
99NPT-161	160.8	7.9	28.9	198
99NPT-162	412.9	8.9	5.3	427
99NPT-163	64	5.7	4.5	74
99NPT-164	2.3	3	1.6	7
99NPT-165	25.5	4.7	4	34
99NPT-166	54	5.3	4.2	64
99NPT-167	351.4	5.4	9.4	366
99NPT-168	254.2	9.2	5.5	269
99NPT-170	119.3	10.7	22.6	153
99NPT-171	81.7	5	6.1	93
99NPT-172	117.1	578.8	336	1032

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.